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PREPARATION OF BATTLE CASUALTIES FOR SURGERY

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IN CARING for the man wounded in battle we are at first concerned solely with what he needs to make it possible for him to withstand transport to the hospital and then to meet the stress of emergency surgery. All else, even the question of ultimate survival, is secondary. The conditions that are to be overcome, the increasing forces that must be opposed, and the means used are the subject of this report. Conditions within the patient arising directly from the wound as well as adverse external circumstances that influence his condition will be discussed, but the emphasis here is on treatment.

THE WOUNDED PATIENT

The enemy has produced the worst wound he could, and its consequences are cumulative—dehydration increased by unusual fluid loss in sweat and vomitus, continuing hemorrhage or plasma loss, pain making rest impossible, increasing emotional exhaustion, developing infection—these and other factors are set in operation by the initial wound. Their progress in the seriously wounded is to be checked in most cases only by surgery or by death. Resuscitative measures give a temporary stay and make successful surgery possible in the severely wounded; but in most cases true release from the consequences of the wound is effected only by surgery. Surgery is not only the goal but is itself a part of resuscitation in the broad sense. Any other view is likely to lead to unfortunate separation between the activities of the "shock team" and those of the surgical team. Care of the wounded man must be continuous and supervision uninterrupted.

Good preparation of the patient for his initial surgery, as well as for the days to come, requires considerate treatment of his pain as well as of a number of psychologic and emotional problems. While lack of understanding in handling these may at the moment be less important than surgical action, a lack of skill here may leave scars as permanently harmful as poor surgery.

PAIN*

The initial assumption of the writer, in common with most physicians

* This has been considered in detail elsewhere. See Beecher, H. K.: Pain in Men Wounded in Battle. In press, 1944.

treating the wounded, was that bad wounds are generally associated with bad pain. This was early found to be incorrect. Careful observers in battalion aid stations estimated that only about one-fifth of the freshly wounded had bad pain. Random samplings of groups of patients in the rear supported this view; but it was feared that in these cases too much time had elapsed to permit accurate evaluation, and that possibly the patients were amnesic for the early hours following wounding. Accordingly, when it became possible to study wounded men in the most forward hospitals on the Cassino Front, at the Anzio Beachhead and later in France, this was done; 225 freshly and seriously wounded soldiers were considered in five groups: 50 patients with compound fracture of a long bone, 50 with extensive peripheral soft-tissue wounds, 50 with a penetrating wound of the thorax, 50 with a penetrating wound of the abdomen, and 15 with a penetrated cerebrum. None of the men considered here was in shock at the time of the questioning. (If in shock at entry, questioning was delayed until this had been overcome.) As nearly as possible consecutive cases were considered. Ten of these had to be ruled out of consideration because they were not mentally clear. Nine of these ten had penetrating head wounds. Disregarding for the moment the entire group of head wounds, only one patient of the remaining 201 was not clear mentally and alert.

Of all of the various types of wounds considered, patients with penetrated abdomens have by far the most pain. This may be due to the spilling of blood and intestinal contents into the peritoneal cavity. Infection may have a part in producing the severe pain observed. Only one-quarter of all of the patients on being directly questioned soon after entry in a forward hospital said they were having enough pain to want further pain relief therapy. Three-quarters did not wish such relief, notwithstanding the fact that the most recent morphine had been given several hours before (4.8 to 7.2, average for the various groups). In the paper referred to, evidence is presented to show that the difference between the one-quarter of the seriously wounded men that wanted further pain relief therapy and the three-quarters that did not, cannot be explained by differences in dosage or timing of the morphine administered. From the data presented it is clear that morphine is, unfortunately, often administered by rote and not according to need. The use of morphine in the treatment of pain was considered in detail in the other paper and will not be discussed further here.

Thoughtful appraisal of wounded men will show that wound pain is only one cause of suffering. Mental agitation and thirst are factors that may be as important to the patient as pain. The excitement and hyperactivity sometimes encountered in the wounded and ascribed to pain may have their origin not in pain, but occasionally in cerebral anoxia, and more often in mental distress. Repeatedly it was found that a small dose of a barbiturate would provide relief not obtainable by reasonable doses of morphine. Barbiturate sedation offers a real addition to the treatment of the distress of wounded men. Small doses of barbiturates (60 mg. sodium

amytal intravenously) and small doses of morphine will frequently accomplish what large doses of either will fail to do satisfactorily. (See *loc. cit.*)

In men in severe shock thirst causes more suffering than wound pain.

In terms of planning, care for the mental and emotional problems of the patient falls within the sphere of the chaplain and the psychiatrist. In practice they often have to be dealt with by the medical officer in charge of the preoperative ward, or by the surgeon. Since part of the rôle of chaplain or psychiatrist may have to be assumed at times by the ordinary physician, some of the responsibilities to be encountered will be mentioned.

THE PHYSICIAN

His Relationship to the Patient.—In the psychologic preparation of the wounded soldier for operation, one must bear in mind that in a high percentage of cases these men are young and their reactions immature. The usual emotional instability of youth has been exaggerated by harrowing experiences. As a result of these the injured have wounds, pain, fear, anxiety. Paternal authority and guidance have been lost and must be assumed by someone. The wounded man seeks it in the chaplain, in the doctor or in his nurse.

Following the confusion of the early hours after wounding, some patients become euphoric. While this is probably more often to be encountered in the early postoperative period, it is sometimes met in the preoperative ward, and may be based upon the overwhelming realization that come what may, the war is suddenly over for the individual. Later the realization that for a longer or shorter time the independent man has become dependent: self-reliance is no longer enough, and a profound depression may follow the euphoria. Major Douglas Kelling observed this sequence strikingly in his study of men who had amputations.

The surgeon's first approach to his wounded patient is the most important. He should hope to portray the trusted family physician, being cheerful and self-confident but not casual. This confidence in his own ability is transferred to the patient. (The tactful chaplain will further build up the patient's confidence in the surgeon.) Consultations in the view of the patient are to be avoided. He is likely to think he is worse than the facts justify.

What to tell the wounded patient who asks questions is one of the most difficult problems of the preoperative period. In the case of the correctible wounds—even amputations are in a sense correctible—much can be accomplished. If the need for an amputation is probable but not certain, tell the patient it may be necessary, but that everything possible will be done to save his limb. If the patient will unquestionably have to have an amputation, his general condition permitting, he should be told before operation. But do not leave it there. Point out that many others have had this same experience and have gone on to live normal lives, both maritally (there is much anxiety concerning this) and economically normal.

Failure to tell a patient ahead of time that an amputation, for example, will be necessary may lead to lack of confidence in his future care.

Far more difficult problems are the "uncorrectible" lesions—great facial disfiguration, total blindness, loss of genitalia, spinal cord transection. The extent of these wounds is usually not certain before operation and positive statements concerning them usually must await operation. The only help such a patient can be given is confidence that he will get good care and that everything possible will be done; definite answers to his questions cannot be given until later. The proper psychologic handling of this group of patients needs study.

Relationship of the Physician to the Chaplain.—The commanding officer or the physician in charge of the patient is often inclined to appraise the value of the chaplain in terms of his (the officer's) personal need for religious support rather than according to the need of the newly wounded man: "There is nothing the chaplain can do that the good physician cannot accomplish." Nonetheless, a fair minority of the seriously wounded are not mentally at ease until they receive spiritual attention. They are lacking and suffer without it. The physician who assumes that he is good at handling such matters often is very bad.*

The physician too infrequently recognizes that a man's spiritual life is a private matter and is too often reluctant to grant that opportunity for private discussion desired by the patient. (Chaplain M. I. English: This can be compressed to two minutes.)

Dividing the army into two classes, the following generalizations can be made: (a) The enlisted men (in the combat zone at least) are far more religious than expected; where they have grown away from the church, it is usually through carelessness, a passive process. The enlisted man has confidence in the help the chaplain can bring. He wants religious help in a crisis. (b) The officer class presents more education. Members of this group often actively reject religion through an intellectual process. Others are indifferent or "superior" on a "logical" basis. Still others, and many of the best officers are in this group, on recognizing intelligence in the chaplain equal to their own, will act on the assumption that the chaplain knows what he is up to. Since he is not stupid and really believes he has something to offer, the chaplain is permitted to go ahead, although many of these same officers would be hard put to it to give a rational description of what the chaplain could do.

The physician must beware of projecting pastoral care upon the wounded man too abruptly. "Am I that bad, Doc?" The chaplain can stroll in and approach the patients casually, not as though he were arranging a volley ball match and time was short.

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* The writer is particularly indebted for good advice on these matters to Captain M. I. English, a chaplain of wide experience in dealing with the freshly wounded, and to Major Douglas Kelling, Psychiatrist for the 45th Division, also widely experienced with such problems.

THE CHAPLAIN

The successful chaplain, if he is to care well for the wounded, must grasp the fact that the soldier has been torn from his familiar life and thrown into a strange milieu where old standards of conduct are ignored or escaped deliberately. The patient's animal spirits have led to adventures that he knows to be wrong, according to his earlier training. He is wounded and suddenly, unlike the pious old lady who has contemplated death for years, new thoughts of death are thrust upon him with insistence. "As soon as I got wounded I thought: 'Damn it, I would have to die without the priest.'" He is confused, but mostly he is frightened, and the chaplain as an expert in straightening out misadventures is heartily welcomed. Major Kelling confirms Chaplain English's statement that feelings of guilt are common in the wounded and that discussion of these with the chaplain is helpful to the patient's effort to acquire serenity.*

The presence of the chaplain is especially important to those whose religions embody a ritual of death, chiefly Catholic. "Am I to die?" Priest: "Some do; you might." Contrary to widespread assumption the administration of extreme unction need not alarm. While the point of view is difficult for the writer to accept, both experienced chaplains and experienced psychiatrists insist that it is sometimes desirable to tell a man he is going to die, that such knowledge correctly imparted does good. "My religion is supposed to help me now," and anguished hope gives way to tranquility is the idea. Maybe so, but certainly with the improvements in medicine of recent years, more caution than ever before is necessary if such statements are ever justified.

ADVERSE EXTERNAL CIRCUMSTANCES

In a study by Beecher and Burnett** it was shown that about 2.5 per cent (of 2853) wounded men arrived at an Evacuation Hospital† in need of particular care in resuscitation, with surgical shock either seriously impending or present. Conditions and processes within the patient in part responsible for the poor condition of these patients were referred to above. External circumstances that tend to increase the number of patients arriving at the hospital in poor condition are chiefly these:

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* In the experience of the writer, apathy is uncommon in the preoperative ward; sometimes it will be encountered, particularly in those with head wounds, occasionally in men in shock. Anxiety and pain may have led to the need for and use of sedatives and narcotics. Later, memory of this period is often found to be lacking. During convalescence the wise chaplain may be obliged to go over the same ground in discussion several times.

** Beecher, H. K., and Burnett, C. H.: Report to the Surgeon, North African Theater of Operations, July, 1944. Field Experience in the Use of Blood and Blood Substitutes (Plasma, Albumin) in the Treatment of Seriously Wounded Men. The Medical Bulletin of the North African Theater of Operations, **2**, No. 1, 2, July, 1944.

† Most of these (2296) were at Anzio, where the hospital bore the same relationship to the front as a field hospital.

Exposure.—This theater has provided a rich variety of geographic and climatic conditions, desert heat and mountain snow storm, dry country and marshes, high elevation and low. Whether exposure may lead to heat exhaustion or to freezing, it is usually associated with inadequate food and fluid intake and with poor rest. *Delay* in the field or along the evacuation chain lowers the patient's reserves. *Rough handling* may be unavoidable in litter transport down mountain trails, or in prolonged ambulance hauls over rough roads; but it often precipitates shock. *The forward treatment* received in Battalion Aid Stations, Collecting Companies and Clearing Stations will be considered below under various headings. In passing, it may be mentioned that this occasionally accounts for part of the poor condition of casualties as they arrive in the forward hospital. Common errors: Overmedication (morphine), too much plasma or too little, failure to recognize and close an open pneumothorax, failure to check serious hemorrhage, transport of patients with head and pharyngeal wounds on back instead of prone as they should be, failure to protect the patient properly during transport. This ranges all the way from poor splinting of broken bones to inadequate blankets, especially underneath the patient in cold weather.

Chart I shows, for the several types of installations, size, position, representative distance apart, duration of the patient's stay in, and the usual means of his transport along the line of evacuation. In the *Battalion Aid, Collecting* and *Clearing Stations* only the simplest procedures are undertaken, and these with the single aim of making the wounded man transportable—splints and tourniquets are applied, hemorrhage staunched, bandages placed, sucking chest wounds closed, plasma and morphine administered if needed. Nothing is done here that will make the man non-transportable.

At the Clearing Station the patient's condition is appraised and a decision reached as to whether he must be taken at once next door, to the Field Hospital, for initial emergency surgery, or whether it is probable that he can withstand the further journey of several miles to the Evacuation Hospital where surgery will be carried out. Minor as well as major wounds are treated in the Evacuation Hospital.

Many factors in addition to the patient's immediate condition must influence the decision in the Clearing Station of where to send him: whether the road connecting with the Evacuation Hospital is good or bad, long or short, difficult for blackout driving or not. Also pertinent is the fact that conditions in the Field Hospital are likely to be, because of the very nature of the installation, less satisfactory than in the larger, more completely staffed Evacuation Hospital farther in the rear. This is no commentary on the staff of either installation. For that matter, the mobile auxiliary surgical teams are important in both. With their smaller staff resuscitation may be slower in the Field than in the Evacuation Hospital. Conditions for postoperative care may be poor in the former. For example, the Field Hospital is often far forward, near, and sometimes in front of, the heavy

artillery positions. The cannonading makes it difficult for the postoperative patient to get the rest he needs. But the well-placed Field Hospital significantly shortens, in comparison with the Evacuation Hospital, the time between wounding and definitive surgery. In cases where time or poor condition contraindicate farther transport, the Field Hospital is invaluable.

CHART I

THE EVACUATION CHAIN

Representative Distances and Usual Type of Transport

LINE OF COMBAT

(The casualty remains here from minutes to days following wounding)

500 yards (litter carry or walk)

BATTALION AID STATION — BATTALION AID STATION — BATTALION AID STATION

(minutes to hours here)

1 mile (litter carry or walk)

COLLECTING STATION — COLLECTING STATION — COLLECTING STATION

(minutes to hours here)

5 miles (ambulance)

FIELD HOSPITAL — Adjacent litter carry — DIVISION CLEARING STATION (100 beds)

PLATOON (100 beds)

(1-12 days here)

(minutes to hours here)

5 to 15 miles (ambulance)

EVACUATION HOSPITAL (400-750 beds)

(1-12 days here)

Up to hundreds of miles (railroad, motor, water or air transportation)

FIXED HOSPITALS

Station (250-400 beds)
General (1000-2000 beds)

Eventually, the patients operated upon in the forward area are moved to the rear. As many as possible are returned to duty wherever this is possible along the evacuation chain. If this is out of the question the patient is moved as soon as possible to the fixed installations, the Station and General Hospitals. Here reparative surgery designed to return the patient to duty, to speed healing, to prevent irreparable damage or deformity is carried out. (Since these units serve garrison troops emergency surgery is also undertaken in them.)

MANAGEMENT OF THE PREOPERATIVE AND SHOCK WARDS

During the Tunisian, Sicilian, and Italian campaigns many arrangements for handling preoperative patients were tried out. Many of these plans ended in acute dissatisfaction on all sides. While details of arrangements will (and should) vary from one installation to another, experience has shown that the most satisfactory plans all embody the following:

Personnel for Field Hospitals.—The continuous service of one man in charge is important for a period of weeks at least. This individual will be chosen from the internists or the junior surgeons. Indefinite assignment of a surgeon to this post usually leads to discontent and eventually poor care. Twelve-hour stretches of duty are satisfactory, even during heavy drives; but longer periods of work will in two or three days lead to inadequate performance during rush periods. One man must be in charge; but another physician should be trained to cover half of the 24-hour day. At least one nurse or corps man (preferably both) should be on duty at all times to assist the officer in charge.

Personnel for Evacuation Hospitals.—Here, again, one man should be in charge, but unlike the Field Hospitals where all admissions deserve "shock" treatment, the majority of patients in the Evacuation Hospitals do not need detailed resuscitative measures (about 2.5 per cent do). In the Evacuation Hospitals, because of the large volume of patients during drives, two officers should be on duty at a time. One man directs the flow of patients through the preoperative ward to surgery and separates out the patients who are in poor condition. These will be given into the care of an officer who will attend the severely wounded men in poor general condition. At least two corps men and two nurses on duty will be needed at all times.

Relationship of the Surgeon to the Preoperative Ward.—A common and serious mistake occurs whenever this ward is used as a kind of valve to regulate the flow of patients to surgery. The optimum time for surgery will be discussed below. There is no known relationship of it to the number of casualties awaiting treatment, presupposed in the flow-meter point of view. The preoperative ward functions satisfactorily only when the surgical chief of service makes frequent visits to it, for he, in collaboration with the officer in charge of the ward, is best qualified to establish priority of operating time. As early as possible cases awaiting operation will be assigned to specific surgical teams. The surgeon, whose patient a given case is, will then, insofar

as it is possible, share in decisions regarding preparation for operation. It is difficult to overemphasize the error of any system which permits one group, as that in the preoperative ward, to carry a patient so far and no farther, then to have his care assumed by a new group, the surgical team, completely unfamiliar with the patient. Good care necessitates continuity of attention.

Routine Procedures in the Preoperative Ward.—The care of the badly wounded patient will be described below; but, in general, all clothing is removed at once on admission of the patient. Many flagrant oversights have their origin in failure to observe this simple direction.* The litter is checked for adequate blankets under as well as over the patient. A complete physical examination is made, and his care planned. If in poor condition, he is sent to the part of the tent set aside for such patients, under the care of the "shock team."

THE PREPARATION OF THE BADLY WOUNDED MAN FOR SURGERY

Surgery imposes a strain; how severe it may be is suggested by the following figures, on the duration of typical operations in the combat zone:

TABLE I

DURATION OF 130 TYPICAL MAJOR OPERATIONS†

Operation	Number of Cases	Average Duration (Minutes) (Anesthesia Induction Time Not Included)
Neurosurgery:		
Craniotomy (dura opened)	20	109 ± 11
Laminectomy	10	122 ± 7
Celiotomy	20	117 ± 12
Thoracotomy	20	148 ± 14
On Extremities:		
Vascular injury (involving ligation of large vessel)	20	62 ± 5
Compound fracture of femur (includes time to apply spica)	20	83 ± 8
Thigh amputation (guillotine)	20	69 ± 7

Of the wounds considered here, only those of the extremities could be dealt with surgically in one hour; those of the head, chest or abdomen required two hours. In World War I, operations upon the extremities constituted a higher percentage of the total number than now. The belief that major surgery in war time rarely exceeds one hour may have arisen from that earlier experience, no longer typical.

These data on duration of operation are from the Cassino Front and the Anzio Beachhead, chiefly the latter, where the single large hospital area was near, and, unfortunately, often in the scene of action. Many of the wounded at Anzio were injured on the spot, some in the actual hospital

* Consider the patient who accidentally discharged his rifle; the bullet passed between his scalp and the inside of the helmet. It followed the curve of the helmet, reversed its direction, and wounded the man in the buttocks.

† These data were collected from the cases of many surgeons, all able and experienced. Actual operating time (not including anesthesia induction time) is shown. This material is of interest only as it shows order of magnitude. Consecutive cases were chosen without selection. Standard errors of the means are given to show variation.

area, others on the adjacent road, "Purple Heart Highway." One value of Anzio has been to show that even in the midst of military action, surgical technics of accepted peace-time standards need not be sacrificed. (These are jeopardized chiefly by overwork during heavy action.)

The operating times indicated here are typical of practice throughout the forward areas in this theater, as such their implications are rather great. Little different as they are from those of civil life, they symbolize the revolution that has occurred in surgery since the time of the last war. Important factors which make possible such prolonged operating will be discussed later. It is clear, from a consideration of these figures, that the patient must be prepared in the preoperative tent to withstand prolonged surgical stress.

So far in this discussion, the wounded patient and his passage along the evacuation chain have been described. Some indication has been given of the surgical and other stresses the patient must be prepared to meet. Hazards of faulty therapy, chiefly of pain, have been considered in some detail. Most of the matters that have arisen so far have concerned all patients, the lightly as well as the critically injured man. The man who has a slight wound requires little special preparation for surgery. The preparation accorded the badly wounded individual may make the difference between survival and death. What then are the important elements in this preparation?

APPRAISAL OF THE PATIENT'S CONDITION

As already pointed out, under the condition of the Cassino Front and the Anzio Beachhead for example, one could expect that about 2.5 per cent of those wounded would fall into the group that is in bad enough condition to require special resuscitative care. Attention will be directed to the very badly wounded men, since patients in less serious condition require to a lesser extent the same treatment.

Recognition of the man already in poor condition presents few problems. The main difficulty comes in early identification of the patient whose condition is deteriorating, recognition of this early enough to check the destroying forces. Early recognition here means economy of care, more rapid preparation for surgery (indispensable if congestion in the preoperative ward is to be avoided) and in the end more lives saved.

The estimate of which patients will bear watching is usually made on the basis of their immediate appearance: Cool extremities and pale skin, with abnormal delay in filling of skin vessels blanched by pressure. The blood pressure may or may not be below normal. If it is, resuscitative care is obviously urgent. The pulse is usually rapid and of rather small volume. The appearance of the wound, its extent, the presence of signs of considerable blood loss either internal or external as in blood-soaked clothing, a history of delay in hospital admission, of exposure, of exhaustion, are all points of value. Excepting patients with head wounds, the badly injured are nearly

always clear mentally* and can give an accurate account of events since their wounding (although later there may be considerable amnesia for this early period). Great thirst is almost always present and causes much suffering. These conditions give a useful hint of difficulties to come. But most important of all for field use is information concerning the *trend* of the pulse and the *trend* of the blood pressure. The way these swing is of great help in evaluating the patient's condition. A rising pulse rate, a falling blood pressure nearly always forecast immediate trouble, especially if associated with a cool skin, in a man who has been at a comfortable room temperature.

With the fairly general acceptance of the view that the cause of deterioration of the wounded patient's general condition is reduced circulating blood volume, problems of therapy become considerably simplified. This simplification is extended with the further acceptance of the evidence that, excepting the processes that lead to dehydration, fluid lost from the circulation is to be explained by loss at the injury site *alone* (except perhaps shortly before death, when some general increase in capillary permeability may occur as a result of profound anoxia). Therapy falls into three main channels: Treatment of the reduced blood volume; treatment of the local wound; and treatment of pain and mental distress. (See above.)

TREATMENT OF THE LOCAL WOUND AS A PART OF RESUSCITATIVE PROCEDURE

Control of hemorrhage may be accomplished by tying a bleeding vessel, by a pressure-pack or by tourniquet. Tourniquets are useful chiefly as a last resort in the control of hemorrhage, usually in the presence of amputations or near amputations. Since they introduce hazards of ischemia and tissue damage, their use is to be as infrequent as possible. "If a tourniquet is necessary, it is applied as low as possible on a limb. It is not removed until a transfusion of blood or blood substitute is already running into a vein; yet, when it is possible that the limb can be saved, the tourniquet is loosened for a few moments at hourly intervals to avoid tissue damage. In hot surroundings the loosening should be carried out more often. With a hopelessly mangled limb, a tourniquet is applied just below the site of election for amputation. When amputation is performed, the tourniquet is not removed until the extremity has been severed."**

Splinting provides a means of preventing further tissue damage, further blood loss and helps to prevent pain. Often Thomas splints are applied with the laced shoe in place. Swelling distal to the wound soon produces needless and great pain. (The shoe should be unlaced and slit if it is considered advisable to leave it on.)

* By actual count only one out of 201 badly wounded patients (not in shock) was not clear mentally on arrival in a forward hospital.

** General Recommendation Concerning Shock, prepared at the request of the National Research Council. Submitted July 16, 1942, by Beecher, H. K., Blalock, A., Cope, O., Loeb, R. F., and Warren, S.

Surgery as an indispensable element in resuscitation will be considered below in the discussion of the optimum time for operation. It is clear that at times there can be no resuscitation without surgery, for example, when uncontrollable internal bleeding occurs, sometimes when great fecal contamination of the peritoneum exists, when leakage into and possibly absorption from, large areas of devitalized tissue is taking place. Resuscitation can and should continue during surgery.

FACTORS OTHER THAN FLUID REPLACEMENT FOR CONSIDERATION IN TREATING THE DEFICIENT CIRCULATING BLOOD VOLUME

Just as the available evidence points to reduction in the volume of circulating blood as the chief cause of poor general condition in wounded men, so will correction of this factor go far to restore the patient to good condition. The more rapidly blood is provided (within reasonable limits, to be discussed below), the more rapidly restoration of a condition suitable for operation will be achieved. The considerable change that has occurred in practice, even during the Italian campaign, is suggested by the following figures: In the Field and Evacuation Hospitals below Venafro and Mignano (Cassino Front) in November and December, 1943, resuscitation of the seriously wounded to the point of operability often required six to eight hours. This contrasts with the more recent experience of Beecher and Burnett (loc. cit.) where very bad-risk patients were prepared for operation and went to surgery in an average of two hours and 20 minutes. The ready availability of whole blood marked an important difference between the two periods. Men who have lost whole blood need blood replacement. Before a detailed discussion of fluid therapy in the wounded is undertaken, a few other matters related to the circulation will be mentioned:

Position of the Patient.—Probably the wounded patient's general condition is at the worst it has been at the moment of arrival at the forward hospital; the delay, the handling, the ambulance haul have all contrived to make it so. About a quarter of the poor-risk patients arrive with no measurable blood pressure. Rest and elevation of the foot of the litter (about 12 inches) with the head and heart low, usually are followed by return of perceptible blood pressure, even before fluid therapy can be started. All badly wounded patients should be placed in this position at once upon arrival, excepting some patients with head wounds (chiefly those with adequate blood pressure), some patients with chest wounds (chiefly those whose oxygenation is mechanically impaired by the position), and also excepting patients with pulmonary edema.

Unless the head-down position gives rise to obvious signs of distress, labored respiration or cyanosis, it should be utilized even in patients with chest wounds and with head wounds, as long as the systolic blood pressure is below 8 Mm.Hg. When the blood pressure has risen to this level, gradual, slow elevation of the head should be started. As much as 20 to 30

minutes may be needed to get these patients with head and chest wounds up into the semirecumbent position.

Gastric Distention.—Ideally, all wounded patients should have their stomachs emptied* before being anesthetized in order to avoid the chance of aspiration of gastric contents. A further reason for this practice is to be found in the observation that distention of the stomach is great enough in some wounded men to interfere with the circulation, decided circulatory improvement occurring on evacuation of the stomach contents. The mechanism of this is not clear, possibly the greatly distended stomach interferes with cardiac filling. Vagal reflexes are possibly involved.

Heat.—Exposure to cold is not desirable in a wounded man and will affect his condition adversely; so, also, will warming if rapidly carried out. Fluid loss through sweat, increased metabolic needs and dilatation of constricted vascular beds are all possible consequences of the use of heat. The body heat of an injured man should be conserved, rather than heat added. Gradual warming of the chilled man is usually best accomplished by placing him in bed, with plenty of blankets, in a tent at normal room temperature. During even such a gradual warming as this, blood replacement therapy should be in progress. Although the ground was frozen hard and covered with snow in the mountains around Cassino, no occasions were encountered where the addition of heat other than that described above was indicated.†

Vasoconstrictor and "Stimulating" Agents.—These are usually of no value in treating the wounded man. In large dose they are contraindicated.

Oxygen Therapy.—Whether oxygen therapy is actually of life-saving value in treating wounded men is as unproved as it is in treating pneumonia. It will produce definite signs of improvement (lowered pulse rate, better blood color) and, therefore, appears to be justified on a logical basis.

Much is often made of the fact that cyanosis will not appear when the hemoglobin concentration is about one-third of normal, a rare circumstance, at least in the freshly wounded. In 37 of the worst wounded patients filtered from 2853 wounded men, Beecher and Burnett (loc. cit.) found on examining them four and one-half hours after wounding (not yet adequate time for complete blood dilution) the hemoglobin averaged 12.3 Gm. The hematocrit

* This is urgent when food or fluids had been taken as recently as two hours or so prior to the wounding or at any time following the wound. The largest tube that will slip down easily should be used. A little judicious moving of this as it goes down will produce vomiting, much to be desired, since only thus can it be certain that the stomach is emptied. Actual washing of the stomach is to be avoided when thoracic or abdominal wounds suggest that perforation of the esophagus or stomach may have occurred.

† One patient was brought in in May, at Anzio, during warm weather, apparently suffering from blast injury with intracranial damage (? hypothalamic area). His rectal temperature was 84° F., and remained at about this level for many hours. Heat was added here; hot water bottles were used; but it was not until the day following injury that his temperature returned to normal.

spread was as follows:* 5 were in the 20's; 16 were in the 30's; 8 were in the 40's (only one above 44) and 1 was 50. More important than low hemoglobin in the failure to detect anoxia is failure to look for the signs of oxygen shortage. Moderate cyanosis is too often overlooked as a result of hasty examination and poor light in the preoperative tent.

In the patient whose condition is deteriorating, circulatory changes occur characterized by falling cardiac output and decreasing blood volume. After a time the circulating blood volume reaches a fairly fixed level where it remains; but the cardiac output continues to fall.† These factors lead finally to tissue anoxia, with resulting metabolic change and organic damage and eventually to an irreversible state known as death.

Unquestionably, increase in the oxygen tension in the inspired air is desirable in conditions like these; but how much can be expected of it is open to considerable question. At least until the practical aspect of this question can be better clarified, use of oxygen in field resuscitation should continue. Excepting cases of respiratory obstruction or depression, increase in the volume of the blood and the total quantity of circulating hemoglobin is the chief need. (See below.)

Oxygen is most conveniently administered by nasal tube. (Four or five patients can easily be serviced from a single oxygen tank.) The oxygen is humidified by bubbling through a water column. The well lubricated (12–14 French) catheter should be inserted into the nasopharynx until the patient is observed to swallow a bolus of air, and then the tube withdrawn one-half inch and firmly anchored with adhesive tape to the face. The correct distance for insertion will usually be equal to the distance from the ala of the nose to the ear lobe, less half an inch. Most patients will tolerate a gas flow of four to five liters per minute. Gastric distention is to be avoided. This must be watched for in the unconscious man.

If signs of oxygen shortage are not relieved by the intranasal administration, one can give higher oxygen concentrations. For this a closed system with carbon dioxide absorption, as an anesthesia apparatus can be utilized.

Oxygen therapy should be continued as long as necessary to hold the gains it has effected. (Probably 70 to 100 per cent oxygen should not be administered for more than 12 hours, rarely necessary. If high concentrations continue to be necessary the periods when they are employed should be alternated with 12-hour periods of 50 to 60 per cent oxygen.)

* Hemoglobin, hematocrit (and plasma protein) were determined by the "Copper Sulfate Method of Measuring the Specific Gravities of Whole Blood and Plasma," by Phillips, R. A., Van Slyke, D. D., Dole, V. P., Emerson, K., Jr., Hamilton, P. B., and Archibald, R. M., for the Committee on Medical Research of the National Research Council, 1943.

† General Recommendations Concerning Shock, 1943 (Revision of Report No. 1 of July 16, 1942), submitted by Bard, P., Blalock, A., Cannon, W. B., Gregersen, M. I., Harkins, H. N., Loeb, R., Long, C. N. H., Richards, D. W., Jr., and Wearn, J. T., for the Committee on Medical Research, National Research Council.

FLUID REPLACEMENT THERAPY

Administration by Mouth vs. Parenterally.—Discussions of this subject usually begin with a kindly admonition to give fluids by mouth, if the wounded man will tolerate them. The opposite is more nearly in line with good practice: preoperative fluids by mouth are in most cases contraindicated after the patient has reached the hospital where his initial surgery will be carried out. Certainly they are if anesthesia and operation are anticipated in a matter of hours, and almost always this is the case. Gastric emptying time is exceedingly long in the newly wounded man. One can see food and drink regurgitated that were consumed ten hours, or more, previously. It becomes increasingly clear that one of the commonest if not the commonest serious preventable accident to occur on surgical services is aspiration of gastric contents. This may be due to vomiting during anesthesia. Or it may be due to expulsion of gastric contents into the pharynx as a result of surgical manipulation in the upper abdomen, and then followed by quiet aspiration by the deeply anesthetized patient. The accident may be a fatal one. (See preceding section on "Gastric Distention.") Naturally, dehydration is to be avoided, or corrected if present. This is done by parenteral injection, chiefly intravenously. A final point: fluids by mouth very often precipitate vomiting, especially in patients with nausea from morphine, so that the net-result of administration of fluids by mouth may actually be a loss of fluid rather than a gain. Patients get considerable comfort but little fluid from a wet sponge to suck and to moisten their dry lips.

Salt and Glucose Solutions.—These agents are primarily useful for the correction of dehydration. As "blood substitutes" they are not very effective, and are dangerous. The elevation they produce in blood volume and blood pressure is so transient as to be of little value. The fluid leaks out of the blood stream. In the presence of head injuries the intracranial pressure may be seriously increased by these agents if they are used in large enough volume to produce a significant blood-pressure effect. In the presence of pulmonary damage, or if the heart is working under adverse conditions, they may precipitate pulmonary edema or increase it if it is already present.

During periods of heavy action, when scores, even hundreds, of patients may be awaiting surgery in a single hospital,* the maintenance of an adequate fluid intake in these men becomes a difficult problem. Under such circumstances patients who cannot go to surgery until the next day may be given fluids by mouth. The others may be given normal saline subcutaneously or normal saline and 5 per cent glucose, usually intravenously, but never more than one liter at a time, and in quantities just adequate to keep down definite dehydration.

* At one period during the great Anzio drive more than 300 patients were awaiting operation at one time in the 94th Evacuation Hospital. The situation was the same in the other hospitals of the Beachhead. It was immediately relieved by a shuttle of air evacuation planes to the large hospital base at Naples—40 minutes away by air.

Plasma.—The use of plasma as one of the best of the "blood substitutes" is well established. Its use is greatest in the forward installations (Battalion Aid, Collecting and Clearing Stations) where blood transfusion is impossible or its attempt inadvisable, and in the treatment of burns.

Excepting the hemolytic problem in burns, plasma represents the chief need there, for it is the part of the blood lost. Its replacement is indicated. Plasma is a part of definitive therapy. Various rules can be made as to quantity to be used. A common one: Two units of plasma in the first 24 hours for each 10 per cent of the body surface burned, or until important hemoconcentration has been relieved. If laboratory facilities are at hand, give 100 cc. of plasma for each point the hematocrit is above a normal of 45. If the plasma proteins are low, 25 per cent should be added to the calculated quantity of plasma needed for every gram the proteins are below six per 100 cc. Better economy is effected in treating burns if the required plasma administration is spaced over 24 hours than crowded into the early hours, for if more is given than needed at one time it is probably lost from the circulation. Secondary shock from burns may occur many hours following the initial injury. The physician in charge must be alert to recognize and treat the anemia that often develops in these cases.

Curiously enough, a fact that is often not adequately appreciated is that plasma, lacking hemoglobin, cannot be, is not, a satisfactory substitute for blood in the wounded man who is seriously bled-out. This state is common in badly wounded men. The great merit of plasma in these cases is that it temporarily sustains the seriously falling blood volume and decreasing cardiac output; it sustains blood pressure at a level compatible with life for a limited time. *Plasma gives more time to get whole blood into the patient.* It should be considered as a stop-gap and not as definitive therapy in patients who have suffered extensive hemorrhage. It has been repeatedly shown in this Theater that plasma, although it will, in many cases, restore for a time adequate blood volume and pressure, in so doing it often gives a false sense of security to those treating the wounded man. *The patient who has been in poor condition because of blood loss, with low blood volume and possibly low hematocrit, will be often seriously endangered if his blood (and effective vascular) volume is increased by plasma without hemoglobin being added.* Such a patient may superficially appear to be prepared for anesthesia and surgery. The blood volume has been restored and the meager quantity of hemoglobin available diluted. The blood pressure has been restored to the level where the already deficient hemoglobin begins to leak out again. A small further loss of hemoglobin from renewed bleeding or during surgery may be critical and sudden disaster occurs. Unfortunately, this has happened many times. *Plasma alone will not adequately prepare the seriously wounded man for surgery.*

One of the most difficult problems is to determine how much plasma should be given in the forward installations. In the badly wounded, 500 cc. may be given as the initial dose. In general, plasma should be given only to the extent of elevating the systolic blood pressure to about 85 Mm.Hg. The

recumbent patient will not suffer if his skin is warm and of good color when the blood pressure is at this level, and needless loss of hemoglobin will not occur as a consequence of bleeding resulting from pressures that are higher than necessary.

While the total volume of plasma to be employed must depend on therapeutic effect and circumstances not possible to treat in generalizations, it can be said that it is rarely necessary to give more than four units of plasma in the four or five hours that often precede hospital admission of the badly wounded individual.

After a Field or Evacuation Hospital has been entered, *preparation for operation* will utilize about one unit of plasma to three units of whole blood.

Albumin.—This fraction of the blood exerts the greatest osmotic pressure of the plasma proteins; 80 per cent of the colloid osmotic pressure of the normal plasma is accounted for by the albumin present. Beecher and Burnett (*loc. cit.*) have given this agent a field trial and have summarized its advantages and disadvantages as they concern military medicine. On the good side is the fact of its small bulk; 25 Gm. dispensed in 100 cc. solution are said to be roughly equivalent to two units of plasma, when used in the well hydrated patient. This was not demonstrated clinically, but possibly the circumstances of the field testing were not adequate to show this difference. Albumin, as it is dispensed is ready for instantaneous use. No reconstitution is necessary as with plasma. It can be administered in one-third to one-half the time needed for plasma. It is remarkably stable.

Also, to be considered is the following: Albumin is expensive in terms of quantity of blood needed to prepare it. Its molecule being smaller than that of the globulins, presumably leaks out of the blood stream faster than they do. Plasma's natural antibodies have, of course, been eliminated as the albumin is separated out. (How desirable these are may be questioned under the present circumstances.) The use of albumin is undesirable in the presence of dehydration.

Before albumin can be adequately evaluated it needs to be compared in man, with plasma, on the basis of cardiac output and blood volume effects. Oddly enough, this has not yet been done so far as can be found. Certainly the combat zone is not the place to engage in such studies.

In the clinical observations referred to above, albumin was employed in some 200 patients. Blood pressure measurements at about ten-minute intervals were followed in 89 patients who received one unit of albumin and in 61 other patients who received one unit of plasma. The spread of the initial blood pressures was comparable in the two groups, as were age, sex, hydration, wounds and general condition. An average of the data (comparable spreads in both groups) when the initial systolic blood pressure was below 80 Mm.Hg. (See Table II)

Higher initial blood pressure levels were studied with similar results. These data were supplemented by observations of the patient's general condition, peripheral circulation, skin temperature, and pulse rate and quality.

Admittedly, all of these data are based upon relatively crude technics of examination: clinically, they add up to no demonstrable difference between one unit of plasma and one unit of albumin, theoretically much more powerful.

The water administered with the plasma is of course an asset, since the tendency in wounded men is toward dehydration. Concentrated albumin depends for its effect on drawing fluid from the tissues into the blood stream, thus, dehydrating the tissues. In well hydrated patients this is all right; but in dehydrated individuals additional salt and water must be given, usually at the rate of two units of albumin to a liter of normal saline, given intravenously. (Subcutaneous administration of saline or glucose solutions is to be avoided in shock because of the poor rate of absorption as a consequence of the lowered peripheral circulation.)

TABLE II

Factors Considered	Plasma	Albumin
Initial blood pressure (Mm. Hg.)	49/21 (Av. of 19 cases)	47/22 (Av. of 40 cases)
Maximum blood pressure after 1 unit of blood substitute (Mm. Hg.)	88/52 (Av. of 15 cases)	83/53 (Av. of 35 cases)
Time to achieve maximum blood pressure (mins.)	19 (Av. of 16 cases)	22 (Av. of 34 cases)
Time for fall of blood pressure to begin (mins.)	29 (Av. of 9 cases)	33 (Av. of 19 cases)

No significant untoward effects were associated with the use of albumin. In two cases a mild, transient urticaria may have been caused by the agent. Transient moist râles in a patient with a thoracic injury may have been caused by the albumin. (Any sudden increase in blood volume is undesirable in such a case.)

The whole thing boils down to albumin's advantage over plasma being in its small bulk and ready availability. This suggests that it should be useful in Battalion Aid Stations and other difficultly accessible posts especially when transport must be by hand. Conceivably albumin should be of advantage for use with air-borne troops, in ambulance planes, and in submarines, where space and weight are at a premium. Whether in terms of the principles on which army medical supplies are chosen, it is desirable to provide albumin for the exceptional circumstances where it has an advantage over plasma, is beyond the writer's experience.

Blood.—(a) Indications for Its Use: The man who has lost large quantities of blood needs blood replacement. Adequate preparation of the seriously wounded man for surgery and support during surgery are impossible without whole blood. This has been demonstrated in probably every preoperative ward and operating room throughout the Tunisian, Sicilian, Italian and Southern French Campaigns. True resuscitation of the wounded requires whole blood. Such statements in no sense minimize the value of plasma. This agent has superbly filled a great need, discussed above.

The best guides in the field for the use of blood are simple, but of great help: the presence of blood-soaked clothing; the nature and extent and duration of the wound; the rate and quality of the pulse, and its trend;

the level of the blood pressure, and its trend; the peripheral circulation as indicated by temperature of the skin and the speed of the response to blanching by pressure; and the color of the mucous membranes.

Possibly, too much attention has been given to the fact that on many occasions the blood pressure may be normal yet the patient seriously depleted. Although it may be unreasonable, this has led to a tendency to dismiss the blood pressure as a helpful sign even when it is low—a fatal error, on some occasions. More helpful than the level of the blood pressure, is the direction of its swing—a falling blood pressure, a rising pulse rate, are in most cases an urgent indication of the need for blood.

In the early hours after wounding the kinds of laboratory data available in the field are likely to be deceiving: the hemoglobin, hematocrit and plasma proteins are usually only a little below normal, before blood dilution has taken place. (These factors are, of course, of great help in evaluating the needs of the patient postoperatively, after stabilization has occurred.) Plasma volume information would offer real help. At the present time at least its determination is too time-consuming to be justified for routine use. The simple clinical signs referred to above, rightly interpreted, provide the help needed to gauge the quantity of blood to be used in a given case. Indications for the use of blood are inseparably linked-up with questions of speed of administration and volume to be given, discussed in the following two sections.

(b) Speed of Administration: This depends on how critical the state of the wounded man is. Unquestionably, badly wounded patients need prompt care. In the study of Beecher and Burnett (*loc. cit.*) the most seriously wounded patients were found to arrive at the hospital at the Anzio Beachhead (short, good roads) more than four and one-half hours after wounding. This suggests that deliberate appraisal of the case is permissible. It is hardly likely that a few minutes more or less on top of the delay already present, in getting the blood or blood substitute into the patient will make any difference. In fairness, however, it must not be overlooked that the handling and ambulance ride immediately preceding hospital entry may have reduced the patient's condition to its poorest. A quarter of the men in this group arrived with no measurable blood pressure. Often only a few minutes of rest in the head-down position was adequate to permit improvement so that measurement of the blood pressure was possible. Action here is governed by rather arbitrary decision based on experience. If the patient's condition is considered to be desperate (systolic blood pressure usually below 60 Mm.Hg.) he is placed at once in the head-down position (foot of litter elevated about 12 inches) a unit of plasma or albumin started while a transfusion of low titer "O" blood* is obtained. Although patient's blood for later grouping and cross-matching is obtained at the first vena puncture, time is not taken for matching on the occasion of giving the first or at times even the second blood when dealing with the desperately

* Iso-agglutinin titer of 1–64, or less.

wounded. The first transfusion may sometimes be forced in rapidly by using a bulb (from a blood-pressure apparatus) placed on the blood flask's air inlet tube. Rarely this may be necessary for the second transfusion. As soon as the blood pressure has begun to rise, efforts to obtain great speed of administration can be relaxed as long as the improvement continues.

Subsequent transfusions are usually given more slowly: 500 cc. blood in half an hour to an hour. When the systolic blood pressure has risen to 80 Mm.Hg. the latter rate is generally adequate. So, also, is it for the use of blood prophylactically when fall of blood pressure is to be anticipated, but not actually occurring.

For the certain flow of blood in critical periods cannulas should be introduced under direct vision by "cutting down" on the vein. In emergencies two transfusions should run simultaneously.

(c) Volume of Blood to be Used: The young, healthy, organically sound battle casualty will tolerate his wound and the strain of surgery without replacement of all the blood lost. It is unlikely that a 3,000-cc. hemorrhage is often exceeded. Probably a good many lose 1,500 to 2,000 cc. of blood. Accurate observations on this would be interesting. In the study of Beecher and Burnett (*loc. cit.*) of the most seriously wounded (2.5 per cent of 2,853) battle casualties it was found that from the time of hospital entry until definitive surgery was completed one unit of plasma or albumin and 870 cc. blood were needed on the average before surgery. During surgery a further 500 cc. was administered to two-thirds of the patients, while the remaining one-third got an additional 1,000 cc. blood. These patients had come into the hospital (chiefly at Anzio) over fairly short lines of travel from the front (up to ten miles), fairly good roads were available, and the patients arrived as mentioned in four and one-half hours, average, after wounding. Certainly, the quantity of blood administered by no means replaced the quantity lost and yet as evidence that these patients were well prepared for surgery the following can be submitted: In 2,853 patients who were operated upon, none died during surgery. During April and May at the Anzio Beachhead, the hospital death rate in these patients for 1,623 battle casualties was 1.48 per cent. Finally, the surgeons were positive in their statements that they considered these patients well prepared for operation.

(d) Hazards and Reactions: Transfusion of blood, like the transplantation of any tissue, is a complicated process, filled with opportunities for human error. With increasing speed and volume of blood used increased strain is placed on the laboratory and those checking and supplying the blood. It is also possible that the rapid use of large volumes of nontype specific blood may lead to serious, even fatal reactions. Possibly the use of low titer O blood will help to solve this problem. Ideally, type-specific blood should be used in all cases, practically this is often not possible.

Excluding the accidents when clearly mismatched blood has been given, reactions vary all the way from transient and trivial malaise, chills, fevers and urticarias, to fatal urinary suppression. The chills, urticarias, *etc.*, have been

shown attributable in most cases to faulty preparation of the apparatus used, either inadequate cleaning or delay beyond two hours in sterilization after cleaning. These reactions even in the field (94th Evacuation Hospital) can be kept below 3 per cent.

Fatal urinary suppression, with death from uremia, has been found in some cases to be associated apparently with kidney damage arising from free hemoglobin or myoglobin deposited there.

Perhaps when large quantities of blood are used, the red cell destruction to be expected results in the liberation of greater quantities of free hemoglobin in the circulation than the body can cope with. Other suggested explanations of the free hemoglobin-containing kidneys: sulfonamide reactions, also "shock kidney." Exactly what is meant by this last term is not clear, but apparently those who use it refer to a condition in which considerable quantities of hemoglobin or myoglobin are released from traumatized areas. These are absorbed into the blood stream, accumulate in the kidney and appear to impair its function.

One difficulty in determining how much of the kidney problem is to be accounted for by blood and how much by sulfonamide is due to the fact that most patients who have received blood in large quantity have also been liberally dosed with sulfonamides; thus, it has been difficult to separate these two possible causative agents. With the more general use of penicillin, replacing in some cases sulfonamides, the problem of determining responsibility should be easier in the future than it has been in the past. There is the possibility, of course, that sulfonamides, myoglobin, hemoglobin and so on, produce serious kidney damage only in conjunction with some other factors such as low systemic blood pressure.

Two groups at the Anzio Beachhead received identical types of patients; in one the fatal anuria rate was much higher than in the other; yet the use of sulfonamides was not significantly different in the two places. Moreover, since the same types of injury were received in both places, and since several thousand cases were under consideration, the incidence of "crush syndrome" as well as the incidence and duration of low blood pressure was presumably the same in both groups. The group with the higher anuria death rate used considerably more blood and that more rapidly than the other group. It is impossible to say at this time whether or not this is significant. If some as yet unidentified hazard is present in the occasional transfusion and responsible for the anurias, the more transfusions administered, the more anurias one might expect. There is too little evidence at hand to justify much speculation in this direction at present.

(e) Grouping and Cross-matching of Blood: Except for the great emergencies described above, all patient's blood is to be regrouped *and* cross-matched with the donor's blood. It is often stated that this is not possible in practice. The facts are otherwise. Unless great care is exercised in the transfusion of blood the accidents that occur will nullify the value of the procedure. Perhaps in the future fuller information concerning low

titer O blood will reduce the necessity for grouping and cross-matching in the field. At the present time it can be said that there is too little safety in the use of blood unless *both* grouping and cross-matching are carried out. These safety measures need be dispensed with in relatively few cases.

After 1,000 to 1,500 cc. of nontype specific blood have been administered to bled-out patients a new sample of the recipient's blood should be obtained for subsequent cross-matching. This process should be repeated after every additional liter of blood is administered.

(f) Alkalinization of the Patient: The evidence on which to base decision concerning this is not as full as one would like. It is sufficient, however, to suggest that patients who receive 1,000 cc. of blood or more (as well as those who are on sulfonamides) should be alkalinized.

TIMING OF BLOOD ADMINISTRATION AND OF OPERATION

During periods of heavy military action it must be expected that the blood available may be in short supply, at least its provision will be difficult and economy in its use necessary. The quantities of blood previously mentioned as desirable are half to two-thirds those used and recommended by some experienced officers under the same circumstances. The total quantity of blood needed to see a patient through his operation can be greatly influenced by the timing of its administration. To be specific: When a patient has been extricated from his immediately critical condition and must await operation for a considerable period, elevation of his systolic blood pressure to about 85 Mm.Hg. is all that is necessary *as long as his color is good and his skin warm.* He can be transfused immediately preceding surgery. In all cases some of the limited blood supply should be saved for use during and immediately following surgery.

In other cases an individual's wound may be such that definitive surgery is a necessary part of his resuscitation: when profuse internal bleeding is occurring it is wasteful of time and of blood to attempt to get the patient's blood pressure up to normal. One should consider himself lucky if a systolic pressure of 80 to 85 Mm.Hg. can be achieved and then surgery undertaken. This applies as well to other common conditions where full resuscitation is often impossible until the situation has been corrected surgically, for example, where wide fecal contamination of the peritoneum has occurred, where leakage into, and possibly absorption from, devitalized tissue is in progress.

Acceptance of the view that resuscitation can and should continue during surgery will lead to early operation, to be desired in nearly all cases.

It is a matter of considerable surprise to the writer that there has been as much discussion as has taken place in Italy and France concerning the merits of early against late operation in wounded men. Surely, the wound has set several continuing processes in action: there is bleeding and plasma loss from serous surfaces and into traumatized tissues. Contamination leads to progressing infection. With these and other drains upon him, the seriously

wounded patient must have constant external support by way of blood and plasma. If, as a principle, one can say that the smallest quantity of blood and plasma should be used that is compatible with the patient's well-being (until we know more about the cause of the fatal anuria mentioned above, that is an almost obligatory view), then early operation appears desirable on this basis. Unquestionably, delay in operation necessitates the use of larger quantities of blood and plasma to maintain the patient on an even keel than otherwise is the case. A further point is important in this connection. It has been well established in the cases of peritoneal contamination encountered in perforated peptic ulcer that the mortality rate rises sharply with the passage of time. With the grosser tissue contamination met in warfare this is probably also the case. The passage of time is against the patient's good. That early operation is compatible with successful surgery is borne out in the study of 2,853 battle casualties observed on the Cassino and Anzio Fronts, referred to above.

SUMMARY

The enemy has produced the worst wound he could. The immediate physical consequences of the wound and the inseparable mental and emotional problems that arise from it are discussed in terms of what is needed to prepare the wounded man for surgery. Specifically, the distress of the wounded man was found to come from three sources, pain, mental agitation and thirst. Severe pain is usually best treated with morphine; but much that has passed for a response to pain was found to respond to small doses of barbiturates. Pain great enough to require further treatment with morphine was found to be surprisingly infrequent (present in only one-fourth of the severely wounded as they arrived at the most forward hospital). A great need was found in the newly-wounded man for the use of small doses of sedatives of the barbiturate type.

The relationship of the wounded man to those around him, especially the physician and the chaplain, is discussed, with a view to preparing the man for his future care.

The effect of adverse external circumstances upon the wounded man and his course along the evacuation chain are discussed with attention being given to details of the organization and application of supportive treatment which must precede the initial surgery. One clue to the extent of the resuscitative measures that must at times be carried out is to be found in the fact that even in the most forward hospitals, the field and the evacuation hospitals, the average duration of operation for craniotomy, laminectomy, celiotomy, and thoracotomy was of the order of two hours or more (not including anesthesia induction time). Even operations upon the extremities averaged more than an hour. The deliberation in the surgery carried out compares with that of peacetime medicine.

Experience has shown that about 2.5 per cent of battle casualties (under the conditions of study) will require intensive resuscitative measures. The

needs of this desperately wounded group are discussed from three points of view: (a) Treatment of the local wound. Surgery is an inseparable part of resuscitation in its broad sense. On occasion there can be no resuscitation, even temporarily, without surgery (cf. internal bleeding, great fecal contamination of the peritoneum, *etc.*). In any case resuscitation (blood therapy) should continue during and after surgery. (b) Treatment of the depleted circulating blood volume. Here, position of the patient, gastric distention as it interferes with the circulation, application of heat and oxygen therapy are all discussed. Route of administration of fluids, the rôles in therapy of saline and glucose solutions, of plasma and albumin preparations, and of whole blood are considered in detail. In the case of blood administration, problems and hazards concerned with volume and speed of administration are dealt with. (c) The treatment of pain and emotional disturbances is discussed.

The timing of blood administration and its relationship to the optimum time for surgery are discussed, as, also, is the question of slow against rapid preparation for surgery.

GRADUATE SURGICAL TRAINING IN AMERICA*

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FOR THE SELECTION of a philosophical rather than a clinical topic for this address, I make no apologies. In recent years on this occasion we have had so many excellent expositions of clinical subjects that it would be difficult to select one to warrant the imposition upon the time of those courteous enough to listen. The matter of graduate training or graduate education in surgery is one which has engaged the interest of the speaker for many years. In the light of present conditions it should properly engage the interest of all of us. I propose, therefore, to discuss this subject, particularly in relation to American surgery. It follows, that in order to do this intelligently one must first review the past, consider the present and venture a few suggestions regarding the future.

The beginning of the twentieth century saw surgery in America in the hands of "doctors who operated." These men were mostly physicians who, through interest and manual dexterity, were recognized by the public and their fellow practitioners as surgeons. For the most part, these men continued to engage in the general practice of medicine, and it is doubtful whether anyone really confined his work to surgery. It was the usual thing for the so-called surgeon to attend medical cases, deliver babies and to treat diseases of the eye, ear, nose, throat and skin. In general, the surgeon was merely a superior breed of doctor. He acquired proficiency either by long hours spent in the dissecting room or the dead house. In the former he learned anatomy, and in the latter became familiar with the gross appearance of diseased organs and tissues. This knowledge he applied to his practice. Many of the pioneers in American surgery followed this path to glory. In our own city the elder Gross and Agnew may be cited as examples. Later the period of "study abroad" appeared on the horizon, and of this probably the least said the better. Suffice it to say that the recent graduate, or the practitioner of better than average means took a year off and went to Vienna where he acquired or improved a taste for beer, sent postcards to the folks at home, and eventually returned to become a specialist, by announcement. In this country a number of short, or so-called polyclinic courses were given in various medical centers. To these came doctors for surcease from the rigors of practice and a little fun in the big cities. Neither "study abroad" or the polyclinic course had any significant influence on the progress of surgery in this country.

The American College of Surgeons, founded in 1913, represented the first attempt to set up a standard by which true specialization in surgery might be recognized. By this time there was a not inconsiderable number of surgeons

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who, through long apprenticeship and clinical experience, had attained the status of the specialist. In its earlier days the College attempted to formulate requirements for recognition of surgeons. Later it extended its activities to provide the facilities by means of which these requirements might be met. One need only consider the size of the country where surgery was being done in communities varying in population from the metropolitan city to the village to realize the enormity of the task undertaken by this organization. Those who have been inclined to criticize and belittle the work of the College should bear these facts in mind. That a uniform standard, applicable alike to the metropolis and the village, was impossible of achievement should not be allowed to negative the splendid contributions of the College to the cause of American surgery. It follows as inevitable that some unworthy ones were admitted to Fellowship.

Requirements for admission to Fellowship in the College have been gradually raised over a period of years. The present requirements are three years of hospital service, two of which must be spent in a surgical service acceptable to the College. In addition, it is stated that the candidate must restrict himself to "study, diagnosis and operative work in surgery," but in the same section the statement appears that "the minimum participation of specialization may vary according to the character and size of the community in which the applicant resides." Furthermore, it is stated that each application shall be judged upon its individual merits.

In 1915, the first formal Fellowships in general surgery were instituted at the Mayo Clinic, and to date approximately 825 men have completed this training. In 1916, the Graduate School of Medicine of the University of Pennsylvania was organized and offered the first full-time academic course in surgery, which included work in the basic sciences and led to a higher degree. The residency system, originated at the Johns Hopkins Hospital by Osler probably constitutes America's outstanding contribution to training in surgery. To date 41 men have completed the chief residency in surgery at this institution. Of the residency system, more later.

In 1916 the first Specialty Board was constituted in Ophthalmology. The organization of other similar constituted Boards for other specialties followed. The American Board of Surgery was constituted in 1937, and held its first examination the following year. To date 1279 have been certified by examination (1277 men and 2 women). To qualify for examination before this Board the candidate must present satisfactory evidence of at least five years of training following completion of a minimum internship of one year. This five-year period must be devoted exclusively to training and must include work in the basic sciences of Anatomy, Physiology, Pathology, Chemistry and Bacteriology. Three of the five years must be devoted to general surgery; not more than six months' credit is allowed for work in any one of the previously mentioned basic sciences, or to such specialties as Gynecology, Urology, Orthopedics, *etc.* Recognizing the value of a sound basis of general diagnosis and internal medicine, the Board has accepted a full year of residency

in medicine for credit toward the five years' training. In addition, evidence of adequate operative experience is required. The examination itself is comprehensive and rather difficult. From the foregoing it will be obvious that many men who can qualify for Fellowship in the College are unable to qualify for certification by the Board. The most frequent cause of rejection of applicants is inadequate training; failure to limit to surgery ranks second. A limited number of applicants are rejected on ethical grounds; for example, the practice of division of fees.

This brief summary of the past brings us to a consideration of the present status of graduate education or training in surgery.

Today the recent graduate who desires to become a surgeon has several paths open to him. Regardless of the plan the trainee elects, the objectives are the same. He must review the basic sciences with reference to their application to surgery. He will have forgotten much of his anatomy if he graduated from a school in which anatomy is still taught. If he comes from any one of the majority of the leading schools where anatomy in recent years has been compressed into periods of from three to six months, he will not have forgotten it for the simple reason that he has never learned it. With regard to physiology, likewise, the average graduate will recall that most of his undergraduate hours in this important subject were devoted to the making of nerve muscle preparations and recording the responses of the same on a smoked drum. As to the more important matters of the physiology of nutrition, of liver function, *etc.*, he will have at best a very hazy conception. His training in pathology will be somewhat better, but it will probably be some time since he has looked at a slide under the microscope. The failure to correlate these basic sciences with clinical medicine and surgery is largely due to the fact that these departments are for the most part headed by Ph.D.'s who regard the instruction of undergraduate medical students as a penance which must be fulfilled in order to enjoy the facilities for research in pure science. To put all this into the language of the street: "The tail wags the dog."

In addition to building a foundation upon the basic sciences, the candidate must have opportunity to adequately study surgical patients before operation in order to foresee what may happen to them after operation, and provide protection against such eventualities. Above all, he must have opportunity and time to read and to think, and to discuss his problems day by day as they arise with an older, more experienced and understanding preceptor.

The Apprentice System.—This plan, under which most of the senior Fellows of this Academy were brought up, still has a definite place in the education and training of the surgeon, although in recent years it has become fashionable to refer to the apprentice system with something between reluctant tolerance and ill disguised contempt. For many an aspirant to surgical training, however, it offers the only opportunity. Under this system the tyro associates himself with an established surgeon, assists him at the operating table, takes charge of the pre- and postoperative care of patients,

is gradually eased into greater responsibilities and, finally, is permitted to operate independently. During this apprenticeship, unless his chief pays him a salary, which is uncommon, the trainee is hard pressed to earn a living, and in spite of good intentions too often finds it necessary to engage in general practice "on the side." Unfortunately, the general practice often takes precedence over surgical training. This does not infer that by means of the surgical apprenticeship combined with general practice he may not become a competent operator, but he rarely is able to give sufficient time to surgery to become a well-rounded surgeon. Training of this type, in which the trainee conducts a general practice while acquiring surgical experience, is not acceptable for credit by the American Board of Surgery, and is responsible for the rejection of a considerable number of applicants for examination by that Board. Many of these men may qualify for Fellowship in the American College of Surgeons.

The Residency.—Previous reference to this system has been made. As stated, it had its beginnings at Johns Hopkins Hospital. As originally set-up in that institution a young physician spent an indefinite number of years living in the hospital in order to complete his training. With the Hopkins' plan as a working model, the residency system has been extended to practically all teaching hospitals and to many not connected directly with teaching institutions. The properly set-up residency is probably the best system by which a young physician may receive adequate training in surgery. The widest differences, however, exist in these residencies. The council on Medical Education and Hospitals of the American Medical Association, and the American College of Surgeons, maintain services which inspect and approve institutions for such residencies. In their most recent publications the former has approved 275 and the latter 162. Each has set-up standards for approval. On paper these are excellent. In actuality, some of the approved residencies are nothing more than internships in which the trainee is shockingly exploited and spends his time in routine drudgery, failing completely to receive real instruction, and has neither opportunity nor time to think—both of which are essential. It is inevitable that the best residencies are to be found in teaching hospitals. It by no means follows that good residencies are limited to such institutions. It is not necessary that a residency be taken in a teaching hospital, but it is essential that the director of the residency be a teacher. One of the greatest difficulties in the nonteaching hospital is the meeting of the requirement pertaining to instruction in the basic sciences. Both of the approving bodies previously referred to require such facilities, as does also the American Board of Surgery. Provision for instruction in Anatomy, Pathology, Bacteriology and Surgical Physiology is essential. In a hospital connected with a medical school this is a simple matter. In the well conducted nonteaching hospital adequate instruction may usually be provided in Pathology and Bacteriology. Anatomy and Physiology present difficulties, but not necessarily insurmountable ones. In New York City, for example. certain hospitals have negotiated an agreement with Columbia University

whereby a resident desiring to meet the basic science requirements of a Specialty Board may obtain such instruction without cost, other than the payment of a nominal matriculation fee. This plan should be extended to other teaching centers throughout the country. It is already being applied, in part, in two other localities.

Formal full-time graduate instruction in a University School offers a solution to some of the problems which have proved difficult in the apprenticeship and the residency. The University of Pennsylvania was the first to offer such instruction. Organized in 1916, the first group of student physicians was received in 1919. Under this plan a full academic year is devoted to a comprehensive review of the basic sciences of Anatomy, Physiology, Pathology and Chemistry, together with systematic courses in operative surgery on the cadaver and on living animals. In the latter, the major effort is concentrated upon the mastery of fundamental surgical principles, such as prevention and management of shock, control of hemorrhage, prevention of infection, wound healing, *etc.*, rather than upon cutting and sewing—things which, after all, are the easiest that the surgeon is called upon to master. In conjunction with the foregoing, the student physician is afforded ample opportunity to observe the conduct of operations in the many clinics of Philadelphia, and in the University Hospitals, to maintain close contact with the pre- and postoperative care of patients.

From the beginning, the Graduate School has emphasized the fact that it did not attempt to make a surgeon in one academic year, but it has maintained that with such an academic year behind him, the student physician is placed in a position to become a surgeon through additional clinical training. Those of us who, for many years, have participated in this program of graduate education feel that it has a definite place in the making of surgeons and offers a solution to the conspicuous shortcomings of the purely apprentice type of training. That this feeling is shared by many is evidenced by a steadily increasing number of well qualified applicants each year. The Graduate School encourages the continuation of training by placing those who complete the basic year in acceptable residencies. After the satisfactory completion of two years in such a residency the trainee may, upon presentation of an approved thesis, be awarded the degree of Master of Science in Surgery, or upon the completion of an additional two years, that of Doctor of Science. The American Board of Surgery gives full credit for time spent in this program.

The Graduate School should take a more active part in securing clinical opportunities for those who complete the basic year than it has heretofore. Failure to do this constitutes one of the definite shortcomings which must be remedied.

These three plans—the apprenticeship, the residency and the graduate school—are the paths by which the surgical neophyte may arrive. Most men undertaking training under any of these have as their objective certification by the American Board. In the light of experience acquired through partici-

pation in the examinations of this Board, and in the evaluation of candidates for examination, certain conclusions regarding the merits and shortcomings of the three may be drawn. For the apprenticeship plan, on the credit side one finds that it offers probably the maximum of actual operative experience and tends to the development of the ability to think and act quickly. It also offers greater opportunity for a young man to acquire a surgical practice and, hence, financial security at an earlier date. On the debit side, it is unquestionably true that the surgeon trained today under the apprenticeship plan is likely to know much more of the "how" than of the "why" of what he does. If apprenticed to a typical "cutter and sewer" he may see and not perceive, and may accumulate experience which consists, for the most part, of the repetition of mistakes. These men are prone to the early development of cerebral rigidity, characterized by resistance to progress or change, and an attitude of intolerance and criticism toward those whose horizons are not fixed.

The residency, if it be well organized, is without doubt the best form of training. The residency, unlike the apprenticeship is an educational discipline. The resident advances gradually along a well defined path. He is given instruction in the basic sciences as applied to surgery. He is encouraged, or rather compelled, to use his powers of observation in the study of his patients. He must stand up and be counted when it comes to errors in diagnosis, technic or judgment. In the final phase of his training he is given an opportunity to operate independently. He is encouraged to think his problems through and is given constant help and encouragement in their solution. Above all, if the residency is under the direction of a proper preceptor, the candidate can not but profit through precept and example of the one who stands to him *in loco parentis chirurgicae.*

The residency is, however, not without its shortcomings. The question of the optimum length of time which should be so spent has not been answered to the satisfaction of everyone. The original residencies at the Johns Hopkins were of indeterminate duration, and this, in itself, is not altogether desirable. In time the resident who stays too long develops a cloister complex. He becomes so accustomed to having immediately at hand everything to work with, and someone to whom he may always appeal for help in extremity, that he inevitably loses some of the self-reliance which is part of the essential armamentarium of every surgeon who is confronted with surgical actualities. He may remain so long in his institution that his value to the surgically sick public may be permanently impaired. Again, these long term residents sometimes become sidetracked through concentration on some restricted phase of surgery. This is not by way of criticism of the magnificent work that has been done by many such individuals, but it is, nevertheless, a fact that a vast amount of effort, primarily intended to qualify a man to take care of surgical patients has been wasted. For example, it is completely unnecessary to spend five years in a surgical residency in order to make contributions to the literature of the bacteriology of surgical infections. Such a man has not

only wasted his own time but has also prevented another, possibly equally or even superiorly qualified, from becoming a surgeon. In the examination for certification of many men, the product of the protracted residency, the writer has been impressed with the shocking lack of knowledge of certain matters with which all clinical surgeons should be familiar.

Fellowship in the great clinics, of which there are a number in this country, offers certain things which the residency of indeterminate duration lacks. A more realistic attitude toward the practice of surgery is cultivated and the necessity of getting things done is impressed upon the trainee. He acquires a lively sense of responsibility with regard to results. He probably has a better opportunity to become familiar with the correlation of general surgery with the surgical specialties and internal medicine. He definitely does not have the opportunity to operate independently, nor in some instances even to act as first assistant at the operating table. This form of training is an excellent educational discipline, but before the trainee may take his place and receive the stamp of approval as one qualified to undertake unsupervised the complete responsibilities of the surgeon, he must supplement his Fellowship with some sort of apprenticeship or precepteeship. Here, as in the product of the protracted residency, there is a tendency toward intolerance of his less fortunate brethren of the common herd.

The student physician who completes the basic year in a Graduate School must supplement this year by further clinical training if he is to qualify before his examining board. There are, however, each year some who take the basic course in order to fill some hiatus in their training. Many of these have had considerable clinical experience, but feel that they lack knowledge of the basic sciences as applied to surgery. Only occasionally in recent years have those come who desired refresher courses and the policy of our own institution in normal times has been to discourage them. The Graduate School, in spite of all the criticism leveled at it, has served a useful purpose in the past and will continue to do so in the future. It offers to a significant group of qualified student physicians facilities for formal instruction which cannot be obtained elsewhere.

Having considered the past and the present in graduate training in surgery, we now come to the future.

Any discussion of the future must deal with two separate and distinct phases of the problem. First, the immediate post-war period and, finally, the long range aspect. The induction into the armed services of practically all able-bodied physicians of trainee age brought graduate education in the usual sense to an abrupt halt. Those who had partially completed their training were forced to interrupt it. Those who might, in the normal course of events, have begun training were forced to postpone it. Thus, the annual supply of trained young surgeons ceased. A whole medical generation may be conceivably required to remedy the situation thus created. The so-called residency of nine months, which the War Manpower Commission has been graciously pleased to permit, is probably worse than nothing, since it will create a group

of inadequately trained men who will consider themselves as superior to other less fortunate contemporaries who were placed on active duty at the end of a nine months' internship. Of these, it may be truly said that a little knowledge is a dangerous thing. The product of the nine months' residency will have no significant effect on the general problem of developing surgeons in this country. It is a stop-gap to permit the more efficient care of patients—nothing more or less.

In the period immediately following the cessation of hostilities our first consideration should be for those whose formal training was interrupted by entry into the services. To them should be given the opportunity of completing their training should they desire to do so. Replies to questionnaires sent to physicians in the armed forces indicate that a majority of medical officers desire some sort of graduate education upon discharge from the services. The "G. I. Bill of Right" will make this available to all who desire it. We must, therefore, prepare ourselves to provide proper facilities for it. If in any way possible those whose training was interrupted should be allowed and encouraged to return to the clinics from which they came. The problem of evaluating their military service for credit before the Boards is a real one. In all fairness, it must be admitted that much of the experience incident to service will be of little permanent value. The surgery of war is, at best, rough and ready surgery and is largely confined to the surgery of trauma. Even in this restricted field the young surgeon has scant opportunity of following his patients or of knowing what eventually becomes of them. He, therefore, does not learn to know what to expect from what he does. In other words, there is but little chance to acquire surgical judgment. However worthy the service, or patriotic the motive, military service inevitably will occupy a minor place in surgical education. The American Board of Surgery, after careful consideration of every aspect of this problem, has allowed one year of training credit for the first year of service with the armed forces, regardless of how that year is spent. This is a gesture recognizing the sacrifice that the young doctor has made and not an admission that a year in the Army or Navy is the equivalent of a year of training under normal conditions. Beyond this first year credit will depend upon the actual type of service engaged in. If a candidate is assigned to the surgical service of a regularly constituted military hospital, credit may be allowed upon the submission of an acceptable record of service. The Board has not lowered or modified in any way the other requirements for admission to examination, nor has there been any change in the character of the examination itself. To do either would be manifestly unfair to those who have qualified in the past and who will qualify in the future.

It is quite possible that the American College of Surgeons may change its method of admission to Fellowship. A special committee appointed to make a study of the subject has already submitted a preliminary report. The following citations from this report are here given by permission of the chairman of the committee, Dr. Frederick Coller. The question has

been raised: "Could not the American College of Surgeons conduct an examination in the basic principles of surgery, replacing Part I of the examination now given by many boards?" This would, in addition, serve as an initial test for those aspiring to Fellowship in the College. Following this examination, and after further training, those who passed the initial examination would later take the examinations given by the various Boards of the Surgical Specialties. After having passed his particular Board, the candidate would become eligible for Fellowship in the College. This plan would take care of all men intending to limit their work, but it would not take care of a large group of men practising in small towns and who, while doing good surgery, either are unable or unwilling to confine their practice to surgery. The report offers the suggestion that the character of Junior Fellowship might be changed. This might be reserved for those who have passed the initial examination, but subsequently failed to limit their practice. Since the title of Junior Fellow would be for a limited number of years, and be continued only during good behavior, this group would be encouraged to secure further training and to otherwise meet the requirements for certification by a Board and for Senior Fellowship in the American College of Surgeons. Such a plan would bridge the years between the present and the time when enough men with adequate training will be available to every community.

For those who had come within one year of completing their training, the problem is simple. For those who have had less, it will be difficult in direct proportion. For those who would have commenced their training but for the war, it will be most difficult of all. Many of this latter group will be, for one reason or another, permanently lost to surgery. Regardless of the subdivision into which they may fall, each and everyone of these men deserves well of his profession, as he deserves well of his country, and it is the obligation of all of us who are concerned to see to it that he is not let down. This will be no simple obligation to fulfill. With each year of the war the number of men for whom training facilities must be provided after the war will increase. Even before the war there were not enough places where men qualified to undergo training in surgery could obtain it. Thus, the necessity for some long-range plan becomes obvious and naturally merges with the immediate post war problem.

Various estimates of the qualified surgeons required annually to replace those deceased, superannuated, or retired for other reasons, place the figure in round numbers from 200 upwards. These figures are not completely reliable since the methods of arriving at the annual requirements differ considerably. In order to supply 200 completely trained surgeons each year, approximately 1,000 would have to be in training if a steady supply is to be maintained. If more than 200 new surgeons are required annually, the number in training would have to be proportionately greater.

The need for increased training facilities can be met only by the creation of more residencies. There is in the country today a shocking waste of opportunity in this respect. As stated elsewhere, there are countless hospitals

where the men and material are available for setting up excellent training programs if sufficient interest can be aroused. One often hears, when suggesting that such a plan be initiated, that it is too much trouble. Such people require education and should be made to see their responsibilities. No chief of a surgical service who has experienced the satisfaction which attends a well organized residency would ever voluntarily return to a system whereby he depends upon the services of an intern and a part-time apprentice. It is to be regretted that an occasional hospital superintendent questions in terms of dollars and cents the value of a resident to the hospital. These too must be shown the light.

I have attempted in this communication to discuss the past and the present in Graduate Surgical Training in America. Certain aspects of the future have been touched upon. Certain it is that the responsibility for keeping the torch of surgical progress burning will reside for many years to come in the hands of American surgeons. Let us dedicate our best efforts to the end that we may prove worthy of this responsibility.

LOCAL FLUID LOSS, NERVE STIMULI AND TOXINS IN THE CAUSATION OF SHOCK*

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THE RECENT EXPERIENCES OF SURGEONS in both civilian and military practice[1, 2] confirm the experimental evidence submitted during the past fifteen years that local loss of circulating fluid is by far the most outstanding cause of traumatic shock in persons in relatively good general condition at the time of injury or operation. No better proof could be offered than the striking improvement in the prevention and treatment of shock that has been obtained by very adequate and timely transfusions of blood and plasma before, during and after operative care.

Nervous and toxic factors have been investigated, but so far little information has been acquired that is of service in the treatment of the shocked patient. Working on the theory that nerve stimuli from the seat of injury or operation produce shock, attempts were made by surgeons to prevent its occurrence by the blockage of nerve impulses. This was carried out by the injection of a local anesthetic into the field of operation or into nerve trunks, either as a supplement to general anesthesia, in pursuance of the anoci-association technic of Crile,[3] or as the sole anesthetic agent. After years of very extensive trial this method of preventing shock has met with so little success that its use has been practically abandoned. Local infiltration or block anesthesia is used whenever feasible for operation where shock is threatened or present, but this is done because the general toxic effects are usually less than those of general anesthesia and not because of the possible shock-preventing benefits of nerve block. The general toxic effects of spinal anesthesia, except when large doses are given for high anesthesia, are also usually less than those of deep general anesthesia. This is especially true of continuous spinal anesthesia when used in prolonged abdominal operations where good relaxation of the abdominal wall is essential. However, where marked impairment of the circulation from any cause is present before operation, the frequent additional lowering of blood pressure and disturbance of respiration produced by spinal anesthesia contraindicates its use, as the condition may be seriously augmented.[4]

Swingle, and coworkers,[5] have recently concluded from limb trauma experiments performed on dogs, that a flow of nociceptive nerve stimuli from the traumatized area played an important part in the production of the shock that ensued. It was reported by them that when an amount of trauma somewhat greater than that required to produce shock and death within a few hours in control experiments was administered in the presence of procaine

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spinal anesthesia and the anesthesia maintained for three to four hours, the incidence and severity of shock was greatly reduced. In 12 such experiments ten of the dogs showed none of the characteristic symptoms of shock, and recovered. They state: "The evidence was quite convincing that prolonged spinal anesthesia effectively prevents shock resulting from muscle trauma of the type described." And, again: "The evidence indicates that a flow of nociceptive stimuli from the traumatized regions, unless prevented by spinal anesthesia or a local block, is an important contributing factor in the initiation of the shock state which follows the type of muscle trauma employed." Also: "The nervous factor taken in conjunction with the loss of blood into the injured area almost invariably produces shock, but it is improbable that either factor considered apart from the other is sufficient to induce a fatal outcome in the type of trauma employed."

They made use of local block (1) by injecting a 2 per cent to 4 per cent procaine solution either directly into or about the major nerve trunks or diffusely into the muscles of the limbs; and (2) by applying tight constrictors to both thighs. They report that while considerable success was obtained by these methods, they did not give a protection against shock as complete as that afforded by spinal anesthesia. However, because they found these methods partially successful and spinal anesthesia almost wholly so, they conclude that this "seems good evidence for the existence of a nervous factor in this type of shock."

All of their dogs were anesthetized with ether, and when spinal anesthesia was used, a 2 per cent procaine solution was injected at the level of L-3-4 in amounts varying from 1.8 to 3.0 cc., according to the weight of the animal. This reduced the blood pressure to an average of 75 Mm. of Hg. Both hind limbs were then traumatized with a rawhide mallet, after which the ether was removed and the spinal anesthesia continued for three to four hours by two or three subsequent injections of procaine.

They considered the criticism that since the blood pressure under spinal anesthesia was low, the trauma would produce less extensive hemorrhage and, therefore, less tendency to shock from local fluid loss. However, since the trauma was greater than in the control animals and since some protection was afforded by nerve block from pressure by a tourniquet or by procaine infiltration, which caused no fall in blood pressure before trauma, they felt that this criticism had been met. Pooling of blood was found in the traumatized tissues, but no measurement of the amount of local fluid loss was made.

In a subsequent publication[6] the same authors reported that in a very large majority of cases neither cutting of the major nerves to the hind limbs nor complete section of the spinal cord at the level of T-13/L-1 prevented the development of fatal shock after the same kind of limb trauma had been applied. The findings are paradoxical in terms of the previous report of these authors, in which they stated that procaine nerve block or spinal anesthesia is an important protection against shock by eliminating nociceptive

stimuli from the traumatized hind limbs. They also reported that if only the ventromesial portion of the cord with its descending tracts was preserved, the animals were protected against limb trauma shock of the type described; that cutting this area might sensitize to shock by causing vasodilatation and excess pooling of blood in the traumatized region distal to the level of the cut.

Spinal anesthesia produces temporary blockage not only of the sensory fibers but also of all other fibers of the roots of the spinal cord that are sufficiently exposed to the anesthetic agent. Blockage of the sensory fibers arrests not only sensation but presumably nociceptive stimuli. Blockage of the vasomotor fibers is generally recognized as the principal cause of the fall in blood pressure. Blockage of the motor fibers, by paralyzing the voluntary muscles, contributes to the fall in blood pressure by diminution of intra-abdominal tension, by interference with respiration and, according to some authors,[7] by removal of extravascular support of the capillaries, venules and veins, thus, causing a pooling of blood in the involved areas. Blockage of specific afferent pressor and depressor fibers, which are known to exist,[8] might be expected to have little effect on blood pressure since the action of each type of fiber is antagonistic to the other and their effects are neutralized when both are removed.

If some of the findings and interpretations reported by Swingle, and his coworkers, are valid, they call for attempts to extend the field of spinal anesthesia and renewed efforts on the part of surgeons to prevent shock by the blockage of nerve impulses from the field of operation or injury by the use of local anesthetics. In a search for more evidence on this subject, an effort was made to determine how much of the reported protection against limb trauma shock afforded by spinal anesthesia was due to blockage of sensory nerves preventing the flow of presumable nociceptive stimuli from the traumatized field and how much was due to blockage of vasomotor and motor nerves with resultant temporary fall in blood pressure reducing the amount of hemorrhage. Experiments were conducted on 38 dogs, divided into three main groups. The trauma was limited to the right hind limb and the local fluid loss was determined by comparison of the weights of the hindquarters, using the bisection technic of Blalock.

In Group 1, control experiments, the trauma was applied with the nerve pathways of the hind limbs intact and the blood pressure at normal levels. In Group 2 the trauma was applied with the nerve pathways of the hind limbs and much of the trunk blocked and the blood pressure lowered by spinal anesthesia. In Group 3 the trauma was applied with the nerve pathways intact, but with the blood pressure in the right hind limb lowered by ligation of the right iliac artery and one or more proximal branches of the femoral artery. Thus, it was possible to test the relative rôles of nociceptive stimuli and local fluid loss in the production of limb trauma shock in animals both with and without preliminary blockage of the nerve pathways and with and without preliminary lowering of the blood pressure of the traumatized region.

EXPERIMENTAL TECHNICS

The hair of all dogs was clipped from both hind limbs and the torso up to the level of T-13. The animals were then restrained on their backs and anesthetized with ether until the completion of traumatization. The initial and subsequent blood pressure readings were made by punctures of the left femoral artery and the blood samples were taken at the same time when needed. Red count, hemoglobin and hematocrit determinations were made on samples taken before etherization, 15 to 30 minutes after traumatization and at varying intervals thereafter, depending upon the type of experiment and the length of survival. Trauma was applied with an 800 Gm. padded hammer to all faces of the right thigh and upper leg, approximately three-quarters of which was to the anterior surfaces. Blows were so moderated that skin, bones and femoral artery and vein were not broken, as verified by necropsy.

The results in several hundred limb trauma experiments in this laboratory during the past 18 years have shown that there may be considerable variation in the amount of local fluid loss when a uniform technic of hammering is attempted. This is due in part to the human error of varying from day to day the severity and distribution of the trauma, in part to chance injury of larger vessels producing more extensive hemorrhage in some experiments, and in part to anatomic variations in blood supply. In this study, when blows were unintentionally severe enough to tear the femoral artery (one case) or to break the femur (two cases), the hemorrhage was relatively great, shock and death ensued and the experiments were excluded from the three groups.

In those experiments in which the animals were sacrificed termination was effected by ether. Aseptic technic was employed in all experiments in which the animals were returned to their cages and given the opportunity to survive. The increase in weight of the traumatized over the nontraumatized side is recorded in grams, and is also expressed in per cent of the blood volume, which was estimated at 10 per cent of the body weight.[9]

EXPERIMENTAL RESULTS

Group 1.—The results are shown in Table I. In these control experiments, with the blood pressures starting at normal levels, the trauma applied averaged 20 blows per Kg. of body weight. The limb swelled rapidly as it was hammered, and the swelling was extensive in all cases by the time the blood pressure had been definitely reduced to a shock level. The number of blows was varied in two cases to accord with the amount of limb swelling and embarrassment to the circulation. When the blood pressure was read 15 minutes after completion of trauma the pulse was weak and accelerated and the respirations somewhat embarrassed. The pressures declined steadily until death took place.

Careful observation revealed that by far the greatest part of the swelling took place during the hammering, which indicated an early, rapid loss of blood into the field of trauma. Further swelling was most marked during the

first five to ten minutes following trauma, after which the progress was slow and an increase in the spread to the abdominal wall above the limb occurred. This quick retardation of swelling was taken as evidence of early sealing off of the opened vessels under the favorable condition of lowered blood pressure from blood loss. The changes in red blood count, hematocrit and hemoglobin indicated a very slight to moderate blood dilution.

TABLE I

FLUID LOSS IN RIGHT HIND LIMB TRAUMA IN CONTROL DOGS DYING IN SHOCK FROM TRAUMA

Exp. No.	Wgt. Kg.	Control Blood Pressure mm. Hg.	Amount of Trauma Blows/Kg.	B.P. 10 Min. After Trauma mm. Hg.	Survival After Start of Trauma Hrs.	Fluid Loss Into Traumatized Limb		Blood Changes
						Gm.	% of Est. Bl. Vol.	
364	16.8	156	17.0	46	2.5	769	45.7	Very slight dilution
373	12.3	120	20.0	70	4.3	609	49.5	Early dilution with slight terminal concentration
375	20.6	126	20.0	76	4.0	1020	49.5	Moderate dilution
380	10.4	126	20.0	44	1.2	505	48.5	Early dilution. Terminal concentration
381	12.3	144	22.0	65	2.0	499	40.5	Moderate dilution
Averages		134	19.8	60	2.8	—	46.7	

The amount of fluid lost into the traumatized part, as shown by comparative weights of the hindquarters, averaged 46.7 per cent of the estimated blood volume for the group. This is within the range of the average per cent of the estimated blood volume which is obtained on bleeding to death in comparable time dogs anesthetized with ether, and indicates that the fluid lost was very largely blood. Necropsy revealed considerable bruising and maceration of muscles and subcutaneous tissues and extensive pooling and infiltration of fluid consisting predominantly of blood.

Group 2.—In 15 experiments, divided into three series, a 2 per cent solution of procaine was injected intrathecally in amounts sufficient to produce anesthesia in the lower extremities and abdomen and lower the blood pressure to levels within the desired range before the application of trauma. Readings taken from 5 to 15 minutes after injection showed pressures ranging from 82 to 50 Mm.Hg., of which 11 were under 76 Mm.Hg. These pressures were obtained by a single injection of 3.3 mg./Kg. of body weight in seven cases, and by 4.0 mg./Kg. in two cases. In the remaining experiments additional injections of varying amounts were necessary to obtain the desired pressure range.

As soon as the pressure had been lowered within the above range the limb was traumatized, and it was noted that the resultant swelling was much less than that produced by a corresponding number of blows in Group 1. Except for four instances, the procedure of Swingle, and associates, of applying more trauma than in the control experiments was followed. The number of blows per Kg. of body weight was 25 in each experiment except Nos. 372, 376, 382 and 370, in which instances it was 20. When the blood pressures were read 15 to 20 minutes after trauma they were found in some cases to be lower than before trauma, but in most cases they were appreciably higher.

The readings were taken at a time when the vasodepressor effect of the procaine was usually wearing off. By the end of a 45- to 75-minute period of spinal anesthesia, as indicated by the first return of tail or leg reflexes, the pressure had risen much above the shock level, the traumatized limb showed relatively little further increase in size and the animals were free from evidences of shock. The low blood pressure during and for some time after trauma favored the sealing-off of the opened blood vessels and the early arrest of hemorrhage.

Series 1.—In order to determine the amount of local fluid loss from trauma that had been applied at a time of low pressure following a single spinal injection of procaine, five animals were injected, traumatized, and then sacrificed 1.3 to 4.3 hours later. The results are shown in Table II. In

TABLE II

FLUID LOSS IN RIGHT HIND LIMB FROM TRAUMA APPLIED WHILE BLOOD PRESSURE WAS LOWERED BY SINGLE INJECTION OF SPINAL ANESTHETIC. SACRIFICE 1.3 TO 4.3 HOURS AFTER TRAUMA

Dog No.	Wgt. Kg.	Control B.P. mm. Hg.	B.P. After Spinal	B.P. After Trauma Hrs.	B.P. After Trauma mm. Hg.	Sacrificed After Trauma Hrs.	Fluid Loss Into Traumatized Limb Gm.	Fluid Loss Into Traumatized Limb % of Est. Bl. Vol.	Blood Changes
363	11.1	154	66	0.7	96	4.3	358	32.2	Very slight concentration
				3.5	120				
372	17.1	144	58	0.3	32	1.7	420	24.6	Early dilution followed by slight concentration
				1.5	116				
376	11.0	154	60	0.3	44	1.3	244	22.2	
				1.3	128				
425	10.0	120	75	0.25	105	1.3	200	20.0	Slight concentration
				1.25	130				
426	12.5	144	82	0.25	72	1.3	268	21.4	
				1.25	134				
Averages		143	68	...	...	...	...	24.1	

each instance the leg and tail reflexes had returned by the time of sacrifice and the blood pressure had climbed well up toward the control level without resulting in extensive limb swelling. There was little or no evidence of circulatory change beyond a slight to moderate lowering of blood pressure.

The increase in limb volume averaged 24.1 per cent of the estimated blood volume, only slightly more than half that found in the control group, and with but one exception, Dog 363, was below the level at which it might be expected ultimately to produce shock. Necropsy revealed maceration of tissues at the trauma site at least equal to, and in some cases greater than, that observed in the control experiments, but there was a great deal less extravasated blood and plasma. The blood changes were either inconsequential or a slight concentration.

Series 2.—To determine the effect of a more continuous spinal anesthesia on the amount of local fluid loss from trauma, five animals were injected intrathecally with procaine, traumatized and then given subsequent injections at intervals varying from 0.75 to 1.25 hours through the needle which had been left *in situ*. The intervals between injections were determined by the first appearance of tail or leg reflexes. Anesthesia was maintained for

periods of from 3.7 to 4.1 hours. The results are shown in Table III. The doses after trauma were smaller than the primary dose by two-fifths to three-fifths and usually produced less marked and less prolonged lowering of blood pressure. They were sufficient, however, to keep the tail and leg reflexes abolished. At the end of the period of anesthesia the relatively high blood pressure and the responsiveness of the animals attested to the absence of shock.

TABLE III

FLUID LOSS IN RIGHT HIND LIMB FROM TRAUMA APPLIED WHILE BLOOD PRESSURE WAS LOWERED BY SPINAL ANESTHESIA. ANESTHESIA PROLONGED 3.7 TO 4.1 HOURS BY REPEATED INJECTIONS. SACRIFICE 4 TO 5.8 HOURS AFTER TRAUMA

		B.P. mm. Hg.						Fluid Loss Into Traumatized Limb		
			10-15 Min. After	Duration of Spinal After	B. P. After Trauma		Sacrificed After Trauma		% of Est.	
Dog No.	Wgt. Kg.	Control	Spinal Anesthesia	Trauma	Hrs.	mm.Hg.	Hrs.	Gm.	Bl. Vol.	Blood Changes
382	11.1	130	80	3.7	0.4	70	5.8	248	22.3	No change first 2 hrs. Concentration to 4th hr., then moderate dilution
					4.0	107				
					5.7	96				
427	13.6	125	74	4.1	0.2	80	4.3	507	37.3	
					4.0	112				
428	15.3	144	78	4.0	0.2	104	4.0	335	21.9	Slight dilution, then concentration
					4.0	138				
431	13.2	116	66	4.0	0.2	100	4.2	231	17.5	
					4.0	118				
434	12.1	110	64	4.0	0.3	50	4.3	166	13.7	Moderate dilution
					4.3	116				
Averages		125	72	4.0	...	...	4.5	...	22.5	

Sacrifice was made 4.0 to 5.8 hours after trauma and the increase in limb volume averaged 22.5 per cent of the estimated blood volume. This is further evidence of the early arrest and smallness of the hemorrhage resulting from the trauma under condition of low blood pressure. Necropsy revealed that the maceration of tissues and extravasation of blood and plasma were similar in amount to the findings in Series 1 of this group. The red blood count, hemoglobin and hematocrit changes were not marked in any case.

Series 3.—In order to determine the ultimate effects on the circulation of limb trauma performed under a more continuous spinal anesthesia, five dogs were treated as were those in Series 2 except that, instead of being sacrificed at the end of the three- to four-hour period of spinal anesthesia, they were given the opportunity to survive. After taking blood pressures and blood samples, they were returned to their cages five to seven hours from the time they were restrained on the table, and then given food and drink. The limb swelling appeared to be about equal to that seen in Series 2, and all animals were free from shock. The results are shown in Table IV.

On the following morning they had recovered from the general effects of the experiment, and their blood pressures registered in the vicinity of normal. The traumatized limb was much more swollen than on the previous afternoon. After taking blood samples and pressures, the animals were sacrificed and necropsied. There was little or no gross evidence of visceral

changes. Incisions of the traumatized limbs revealed the presence of blood and macerated tissue, and in addition, a considerable amount of edematous fluid. This late shift of fluid to the traumatized part took place concomitantly with the drinking of water and did not impair the general circulation.

TABLE IV

DOGS SURVIVING RIGHT HIND LIMB TRAUMA APPLIED WHILE BLOOD PRESSURE WAS LOWERED BY SPINAL ANESTHESIA: ANESTHESIA PROLONGED 3 TO 4.5 HOURS BY REPEATED INJECTIONS. SACRIFICE FOLLOWING DAY

Dog No.	Wgt. Kg.	Duration of Spinal Anesthesia After Trauma Hrs.	Blood Pressure—mm. Hg. Control	10-15 Min. After Spinal Injection	15 Min. After Trauma	3.7 to 4.8 Hrs. After Trauma	22.5 to 24.0 Hrs. After Trauma	Remarks
370	18.3	3.5	144	76	80	124	124	No shock. Recovered. Drank 1200 cc. water. Sacrificed 23 hrs.
409	11.5	3.0	150	54	56	100	116	No shock. Recovered. Drank 1600 cc. water. Sacrificed 22.5 hrs.
421	9.7	4.5	158	50	70	98	140	No shock. Recovered. Drank 900 cc. water. Sacrificed 22.3 hrs.
423	8.1	4.0	135	75	100	126	154	No shock. Recovered. Drank 1800 cc. water. Sacrificed 24 hrs.
424	11.1	3.0	120	71	108	116	120	No shock. Recovered. Drank 800 cc. water. Sacrificed 23.3 hrs.
Averages		3.6	141	65	83	113	131	

The blood changes are shown in Table V. The only consistent change was a moderate dilution between the last determinations in the afternoon and those of the following morning, which came about with the taking of fluids. During the first four hours of the experiment the changes were either inconsequential or slight to moderate concentration.

Group 3.—In 18 experiments the blood pressures of the limb to be traumatized were reduced, with two exceptions, to a level of 73 Mm.Hg., or

TABLE V

BLOOD STUDIES ON DOGS SHOWN IN TABLE IV

Exp. No.		Control Sample	Samples after Trauma Hrs. 0.3	1.8 to 2.8	3.3 to 4.8	22 to 24
370	R.B.C. M.	7.24	6.40	7.60	7.94	7.00
	Hb. Gm.	16.5	14.6	16.8	16.9	15.4
	Hcr. %	49.5	43.0	49.0	50.5	44.5
409	R.B.C. M.	7.32	7.50	8.60	8.28	7.06
	Hb. Gm.	15.0	15.3	17.4	16.9	14.5
	Hcr. %	45.5	46.5	51.5	50.0	42.0
421	R.B.C. M.	6.56	6.46	6.40	6.72	5.58
	Hb. Gm.	14.7	14.5	14.2	14.9	12.4
	Hcr. %	43.0	43.0	42.5	44.0	36.0
423	R.B.C. M.	7.00	7.48	7.64	7.26	6.08
	Hb. Gm.	15.0	15.5	16.0	15.0	12.4
	Hcr. %	43.5	47.0	48.0	46.0	36.5
424	R.B.C. M.	6.23	6.51	6.46	6.64	5.74
	Hb. Gm.	12.6	13.0	12.9	13.2	11.5
	Hcr. %	37.0	39.0	39.0	39.5	34.0

below, by ligation of the iliac artery and one or more proximal branches of the femoral artery through an incision just above and parallel to Poupart's ligament. The iliac was first ligated and the blood pressure in the femoral artery then obtained. If the pressure was not below 76 Mm.Hg., the profounda femoris was then tied. This usually sufficed, but in a few cases ligation of other proximal branches was required in order to attain lower levels. In some cases the reduction of pressure was below the levels produced by spinal anesthesia in Group 2, but the average for the group was 63 Mm.Hg. The experiments were divided into three series for comparison with those in Group 2.

Series 1.—Studies were made in eight dogs of the early effects on the circulation and limb volume of trauma applied following arterial ligation, but with the nerves left intact. The results are shown in Table VI.

TABLE VI

FLUID LOSS IN RIGHT HIND LIMB FROM TRAUMA APPLIED WHILE ITS BLOOD PRESSURE WAS LOWERED BY PERMANENT LIGATION OF THE ILIAC ARTERY AND ONE OR MORE PROXIMAL BRANCHES OF THE FEMORAL ARTERY. SACRIFICE 1.1 TO 2.2 HOURS AFTER TRAUMA.

			Femoral Artery Blood Pressure mm/Hg.						
			Left		Right After Ligation			Fluid Loss Into Traumatized Limb	
Exp. No.	Wgt. Kg.	Amount of Trauma Blows/Kg.	Before Trauma	1 Hr. After Trauma	Before Trauma	1 Hr. After Trauma	Sacrificed After Trauma Hrs.	Gm.	% of Est. Bl. Vol.
387	10.1	20.0	150	106	54	.	1.1	272	26.9
390	8.3	20.0	140	116 (2 hrs. 110)	70	34	2.2	81	9.8
391	10.2	25.0	170	120	70	38	1.2	172	16.9
393	10.4	25.0	150	130	52	32	1.2	60	5.8
397	9.7	25.0	130	100	54	30	1.4	28	2.9
398	10.2	25.0	150	120	52	32	1.4	96	9.4
399	21.2	25.0	170	135	120	64	1.4	700	33.0
404	9.3	25.0	145	110	28	28	1.5	72	7.7
Averages.....			150	116	63	37	...	...	....

The trauma consisted of 25 blows per Kg. body weight except in experiments Nos. 387 and 390, where it was 20 blows per Kg. Blood pressures were taken from the right and left femoral arteries both before and one hour after trauma (two hours in one case) and blood samples were obtained from the left femoral artery at the same time. It was noted that limb swelling was very slight in most cases, and while there was a moderate reduction in blood pressure one hour after trauma, there were no indications of shock.

The animals were sacrificed 1.1 to 2.2 hours after trauma. Comparison of weights of the hindquarters revealed much variation, but, on the whole, considerably less increase in volume of the traumatized side than was found in Series 1 of Group 2. This was due to the more complete interference with the limb circulation by the permanent ligations, and also to injury of collateral vessels by the trauma, as indicated by the very low pressure readings in the right femoral artery one hour after trauma. Incisions of the traumatized region showed much bruising of tissues but usually relatively little extravasa-

tion of blood or plasma. The red count, hemoglobin and hematocrit determinations revealed very little blood change.

Series 2.—In five dogs subjected to ligation followed by limb trauma of 25 blows per Kg. of body weight, the procedures and findings were the same as in the above series during the first hour following trauma. At this point, however, the ligatures were removed in order to simulate the conditions in Series 1, Group 2, where the blood pressure rose with the wearing-off of the single spinal anesthetic. The results are shown in Table VII.

TABLE VII

FLUID LOSS IN RIGHT HIND LIMB FROM TRAUMA APPLIED WHILE ITS BLOOD PRESSURE WAS TEMPORARILY LOWERED BY LIGATION OF THE ILIAC ARTERY AND ONE OR MORE PROXIMAL BRANCHES OF THE FEMORAL ARTERY. LIGATURES REMOVED ONE HOUR AFTER TRAUMA. SACRIFICE 2.5 TO 3.1 HOURS AFTER TRAUMA.

		B.P. Left Femoral A. mm.Hg.			B.P Right Femoral A. mm.Hg. While Ligated		After Ligature Removed			Fluid Loss Into Traumatized Limb	
Exp. No.	Wgt. Kg.	Before Trauma	1 Hr. After Trauma	Before Sacrifice	Before Trauma	1 Hr. After Trauma	10 Min. After Removal	Just Before Sacrifice	Sacrificed After Trauma Hrs.	Gm.	% of Est. Bl. Vol.
394	19.0	146	130	104	72	50	122	106	2.5	420	22.0
395	22.2	135	110	110	73	40	110	110	2.5	560	25.2
400	15.5	150	140	125	70	48	140	120	2.5	451	29.1
405	17.7	145	130	130	72	48	130	125	3.1	270	15.5
408	18.1	160	130	110	84	46	120	110	3.0	380	21.0
Averages....		147	128	116	74	46	124	114	2.7	...	22.6

Upon removal of the ligatures the pressure in the femoral artery rose promptly to the general level of that obtained in the opposite limb one hour after trauma, and the limb subsequently showed only slight evidence of further swelling. Just previous to sacrifice, 2.5 to 3.1 hours after trauma, the animals were found to have moderate reductions in blood pressure, similar to those of Series 1, Group 2, and, likewise, there were no signs of shock. Comparison of weights of the hindquarters revealed approximately the same amount of fluid loss into the traumatized limb as was found in Series 1 and 2 of Group 2. Expressed in terms of the estimated blood volume, it was less than one-half of the percentage lost in control Group 1. Incisions of the traumatized region revealed extensive maceration of tissues and only a moderate amount of extravasated blood. Blood studies showed either no change or a very slight concentration.

Series 3.—Five experiments were performed in order to elicit the long-term effects of trauma to the right hind limb with its blood pressure lowered by arterial ligation and its nerve pathways intact. The results are shown in Table VIII. The arteries were exposed and tied and the wound closed, using aseptic technic, after which 25 blows per Kg. of body weight were applied. Back pressure in the right femoral artery was read only immediately after ligation. The animals were kept restrained on their backs on the table for four to five hours and during this time the blood pressure, as measured in the left femoral artery, remained either up to the control level or was only moderately reduced. The traumatized limb became slightly to moderately

swollen. When the dogs were returned to their cages they moved about with little difficulty and drank water freely. The following morning they had recovered from the general effects of the experiment and the blood pressures were found to be very slightly to moderately reduced from the initial pressures. Sensation was intact in the traumatized limbs and considerably more

TABLE VIII

DOGS SURVIVING RIGHT HIND LIMB TRAUMA APPLIED WHILE BLOOD PRESSURE OF TRAUMATIZED LIMB WAS LOWERED BY PERMANENT LIGATION OF THE ILIAC ARTERY AND ONE OR MORE BRANCHES OF THE FEMORAL ARTERY. SACRIFICE FOLLOWING DAY

		Femoral Artery B.P. mm. Hg.					
				Left Hrs. After Trauma			
Exp. No.	Wgt. Kg.	Left Initial	Right After Ligation	1	4–5	21–24	Remarks
396	17.5	155	46	130	130	150	No shock. Recovered. Drank 2,100 cc. water. Sacrificed 22.5 hrs.
407	10.6	160	58	130	130	125	No shock. Recovered. Drank 1,700 cc. water. Sacrificed 22.0 hrs.
410	17.2	128	58	128	124	115	No shock. Recovered. Drank 600 cc. water. Sacrificed 21.8 hrs.
413	17.3	180	44	130	180	148	No shock. Recovered. Drank 1,400 cc. water. Sacrificed 22.5 hrs.
414	12.5	166	38	110	136	135	No shock. Recovered. Drank 1,400 cc. water. Sacrificed 23.5 hrs.
Average.....		158	49	126	140	135	

swelling had occurred, as was found in Series 3 of Group 2. Incisions after sacrifice revealed macerated tissues, blood and edema in the traumatized regions and considerable swelling of nontraumatized tissues above and below the site of trauma. The blood changes in the early period were variable and relatively slight, but a slight to moderate dilution was present in all cases on the following morning, as shown in Table IX.

DISCUSSION.—The results in Group 1 are in line with the generally recognized findings in limb trauma experiments that produce death within a few hours. The local fluid loss of an average of 46.7 per cent of the estimated blood volume is within the range of the average blood loss when anesthetized dogs are bled to death in comparable periods of time. The rapid swelling of the limb during and shortly after the trauma, the low blood pressure read ten minutes after trauma, and the necropsy findings of large amounts of extravasated blood constitute convincing evidence that the predominant cause of the shock and death was the loss of blood into the limb. Because of the more marked and sustained vasodepression and the earlier death, it is apparent that the trauma was somewhat more severe than in the experiments of Swingle, and associates.

The results in Group 2 confirm the observation of Swingle, and coworkers, that limb trauma even greater than that required to produce fatal shock in dogs anesthetized with ether during the traumatization does not produce shock or

death if the trauma is applied while the animals are under ether and the blood pressure has been lowered to 75 Mm.Hg., or less, by spinal anesthesia. But a different explanation was found for these results.

TABLE IX

BLOOD STUDIES ON DOGS SHOWN IN TABLE VIII

Exp. No.		Control Sample	Samples After Trauma Hrs. 0.5	1.0	5.0	22 to 24
396	R.B.C. M.	9.30	8.60	8.76	8.44	7.60
	Hb. Gm.	18.5	17.1	17.2	16.9	15.6
	Hcr. %	52.5	50.0	50.0	51.0	46.0
407	R.B.C. M.	9.52	9.90	10.16	9.70	8.94
	Hb. Gm.	19.5	20.3	20.7	19.8	18.3
	Hcr. %	57.5	60.5	61.0	59.0	53.0
410	R.B.C. M.	7.80	8.10	8.44	8.04	7.50
	Hb. Gm.	15.9	16.5	17.3	16.5	15.3
	Hcr. %	47.5	49.0	49.5	49.5	45.5
413	R.B.C. M.	5.56	5.36	5.26	5.40	4.42
	Hb. Gm.	11.4	11.0	10.8	11.1	9.3
	Hcr. %	32.0	31.5	31.0	32.0	26.5
414	R.B.C. M.	7.94	7.30	7.44	6.64	5.70
	Hb. Gm.	15.1	13.9	14.1	13.0	11.7
	Hcr. %	44.0	41.0	41.5	38.0	38.0

Comparison of the weights of the two hindquarters of animals sacrificed soon after either the single or the more continuous spinal anesthesia revealed that the amount of fluid lost into the traumatized limb was approximately but one-half as great as that in Control Group 1. The loss of that amount of fluid (which necropsy showed to be very largely blood) was enough to account for the slight to moderate vasodepression present at the time of sacrifice, but it was not enough to produce shock. The protection against hemorrhage afforded by the low blood pressure from blockage of vasomotor and motor nerves is sufficient explanation for the failure of development of shock and the survival of Series 3. The assumption of important additional protection from the blockage of nociceptive stimuli from the regions of trauma is not warranted.

Just how nociceptive stimuli act in creating shock has not been clearly set forth by the proponents of the theory. From the limb they would pass by the sensory pathways to the cerebrum, principally the cortex, and if it is presumed that further action is through the sympathetics, efferent impulses would then go to the medullary and hypothalamic vasomotor centers and lower the blood pressure. But if spinal anesthesia blocks a flow of nociceptive stimuli from the traumatized limb to the brain and thereby prevents a fall in blood pressure and shock from occurring, it also simultaneously produces a fall in blood pressure by blocking the vasomotor and, very much less importantly, the motor fibers of the spinal roots, which would unquestionably tend to offset the benefits of the first-mentioned action.

When the blood pressure is low from spinal anesthesia and large arteries are opened by the injury to the limb, there may be enough blood loss to constitute the predominant cause of shock and death. This was the case in the three experiments excluded from the three groups. Twenty-five blows

per Kg. of body weight were delivered. In one the femoral artery was torn early in the course of the trauma and a large hematoma collected subcutaneously on the front of the thigh. Death resulted in 2.9 hours and the increase in limb volume equalled 41.2 per cent of the estimated blood volume. In two cases the femur was broken. Death occurred in one of these in 3.9 hours, and the increase in limb volume equalled 30.0 per cent of the estimated blood volume. The other one died after being returned to the cage for the night and the increase in limb volume equalled 35.0 per cent of the estimated blood volume.

The results in Group 3 further challenge the correctness of the view that nociceptive nerve stimuli are an important cause of experimental limb trauma shock. With the nerves intact in this group, the flow of nociceptive stimuli from the traumatized field should have been at least as great as in Group 1, and greater than in Group 2, because of the periods of spinal anesthesia. And still none of the animals developed marked lowering of blood pressure or other manifestations of shock. The objection might be raised that the nerves of the traumatized limb in Group 3 would be less sensitive to stimuli during and shortly after the trauma than those in Group 1 because of the greater average lowering of blood pressure and interference with nutrition. However, as the early pressure levels of the traumatized limbs of the dogs of these two groups were comparable in some cases, and the trauma was greater by 25 per cent in 16 of the 18 experiments in Group 3, this should have compensated for any reduced sensitivity. In all three series the general blood pressure one hour after traumatization was slightly to moderately reduced except in one experiment. In Series 2 the reduction was either maintained or slightly augmented 2.5 to 3.1 hours later, but in Series 3 there was a tendency to elevation of pressure in four to five hours. The changes in pressure may well have been due to the local fluid loss except in four of the cases of Series 1, where it was too small to have been the sole factor.

From a survey of the findings it is apparent that when the limb of an animal is traumatized at a time when its blood pressure is greatly lowered, there is a definite protection against shock because of local hemorrhage being considerably less than is the case when the blood pressure is at a normal level. The results were about the same whether the nerve impulses from the limb were blocked, as when spinal anesthesia was used, or not blocked, as when the arteries were ligated, so long as the blood pressure in the limb was kept at comparably low levels.

When these findings are considered along with previous findings that direct stimulation of the large nerves of the limb may be kept up for hours without causing a significant fall in blood pressure, and that stimulation of the carotid sinus and aortic depressor nerves may maintain a low blood pressure for as much as several hours without serious impairment of the circulation,[10] the evidence is strong that afferent nerve impulses from the field of injury are not factors of great importance in limb trauma shock of the type described here.

The experiments deserve consideration from the standpoint of a toxic factor in traumatic shock. If toxins are formed in the traumatized tissues, the greater the degree of trauma the greater should be the amounts produced. If this is true, the animals in Group 1, which received an average of 20 blows per Kg. of body weight, should have shown no more toxic effects than did the great majority of those in Groups 2 and 3, which received 25 blows per Kg. of body weight. Since the local loss of fluid was so evidently the predominant cause of circulatory embarrassment and death in Group 1, and since any circulatory damage that may have occurred in the more severely traumatized Groups 2 and 3 was so minimal as not to cause shock or death, there is little reason to believe that, if toxins were formed in the damaged tissues, they were an important cause of the circulatory difficulties of animals in any of the three groups.

EFFECTS OF CORD, NERVE AND DORSAL ROOT SECTIONS

If, as was reported by Swingle, and coworkers, the complete and permanent blockage of all impulses from the traumatized regions by preliminary section of the nerves of limbs or of the spinal cord at T-13/L-1 does not prevent limb trauma shock of the type described, while temporary blockage for four hours by local procaine injections and for two hours by tourniquet constriction prevents shock, the reason could not possibly be blockage of nociceptive stimuli. They postulated that the nerve or cord sections had permanently removed some nervous factor tending to maintain the resistance of the animal to shock. In consequence they made studies of a variety of partial sections of the spinal cord at T-13/L-1 in an attempt to obtain more specific information regarding the site of a factor, the lack of which apparently sensitized the traumatized dog to shock.

Section of either the anterior or posterior half of the cord failed to prevent the occurrence of shock, but if the ventrolateral areas of the anterior half were cut while the ventromesial areas were preserved, the animals were protected from shock. The ventrolateral areas appeared to be the most important areas in the production of shock. The ventrolateral areas include, among others, the dorsal spinothalamic ascending tracts which transmit pain stimuli and are also presumed to transmit nociceptive stimuli. It was reported that the descending tracts contained in the ventromesial areas of the cord are concerned in maintaining the resistance of the animal to shock from muscle trauma. Destruction of these areas might result in vasodilatation of the blood vessels distal to the cut, produced either directly or indirectly through loss of muscle tone. This vasodilatation should increase the fluid loss into the limbs during the actual traumatization by an amount sufficient to be an important factor in the production of shock.

If impulses passing over the descending tracts in the ventromesial areas of the cord protect against shock from limb trauma, and if nociceptive stimuli passing over the pain or other afferent fibers of the dorsal spinothalamic or other tracts interfere with this protection, as suggested by the authors,

then preliminary section of the dorsal spinal roots, thereby interrupting all afferent impulses from a limb, should protect against shock from trauma applied to that limb.

This premise was tested experimentally on four dogs as follows: Under intravenous evipal anesthesia a laminectomy from T-13 to S-1 was performed, the dura opened and all dorsal roots on the left side below T-12 were sectioned. Aseptic technic was used except on one animal which was experimented on acutely. Because of considerable degrees of hemorrhage in experiments Nos. 333, 341 and 345, electrocolorometric determinations were made

TABLE X

SHOCK FROM TRAUMATIZING LIMB AFTER SECTION OF ITS DORSAL SPINAL NERVE ROOTS

Exp. No.	Wgt. Kg.	Initial Pressure mm. Hg.	Elapsed Time Between Root Section and Trauma	Blood Pressure Before Trauma mm. Hg.	Amount of Trauma Blows/Kg.	Survival Period Hrs.	Fluid Loss Into Traumatized Limb		
							Gm.	% of Est. Bl. Vol.	Blood Changes
333	13.3	116	4 hours	98	15.0	1.8	464	34.9	
341	7.9	150	2 days	116	17.1	1.5	372	47.3	Moderate dilution
338	9.4	140	3 days	156	18.6	1.9	446	47.4	
345	11.3	164	6 days	130	11.0	3.3	520	46.0	Slight dilution

of the amounts of blood lost on the sponges and drapes and equivalent transfusions were given. Left limb trauma under ether was applied four hours and two, three, and six days after dorsal root section. All animals were in relatively good general condition at the start of the trauma. The trauma was made somewhat more severe by the use of heavier blows than was given in the three groups reported above, as it was the intention to produce rapid circulatory embarrassment and early onset of shock. The results are shown in Table X.

The average period of survival was somewhat shorter than in Group 1, but the average amount of local fluid loss into the limb in terms of per cent of the estimated blood volume was approximately the same in both groups except for the acute experiment, No. 333, where only four hours had elapsed between the surgery and trauma. Red blood count, hemoglobin and hematocrit determinations revealed very slight to moderate blood dilution.

Contact with the cord during surgery was avoided as much as possible in order to prevent injury and in no case was there instrumentation of the ventromesial areas. Consequently, the descending tracts in the ventromesial areas of the cord were left intact while the fibers of the dorsal spinothalamic and all other tracts which might transmit pain and presumable nociceptive stimuli were destroyed.

There appeared to be no concrete evidence in these experiments that the animals were protected against shock by destruction of the pain and other afferent fibers of the cord by dorsal root section, even though the descending tracts of the ventromesial areas were left intact, since they tolerated trauma and blood and plasma loss into the limb no better than did the normal dogs of Group 1.

SUMMARY

Experiments were conducted on dogs in an endeavor to determine the relative rôles of nerve impulses and local fluid loss in the production of shock due to limb trauma. They were undertaken because of work reported by Swingle, and associates, which indicated that a flow of nociceptive stimuli from the traumatized regions, unless prevented by spinal anesthesia or a local block, is an important contributing factor in the initiation of the shock state which follows. The spinal anesthetic lowered the blood pressure to 75 Mm.Hg., or under, before the trauma was applied.

The experiments were divided into three groups, the trauma was limited to one limb and the local fluid loss was determined by comparison of the weights of the hindquarters. Trauma was applied during ether anesthesia and consisted of moderate blows from a padded hammer.

In Group 1 it was applied with the nerve pathways intact and the systemic blood pressure at normal levels. An average of 20 blows per Kg. of body weight caused rapid and marked swelling with early onset of shock and death after an average of 2.8 hours. The fluid loss into the limb, consisting predominantly of blood averaged 46.7 per cent of the estimated blood volume. It was obviously the outstanding cause of shock and death.

In Group 2 the trauma was applied after the nerve pathways to the hind limbs and lower trunk were blocked by spinal anesthesia and the blood pressure lowered to 75 Mm.Hg., or under. In the majority of experiments 25 blows per Kg. of body weight were used, but in a few it was limited to 20, as in Group 1. The swelling was much less marked than in Group 1, and in no instance did shock develop. In those animals sacrificed shortly after periods of either single injection or continuous spinal anesthesia the local fluid loss was approximately one-half that found in Group 1, and it was not sufficiently large to produce shock. The animals which were allowed to survive were in good general condition on the following day.

In Group 3 the trauma was applied with the nerve pathways to the limb intact and with the blood pressure in the limb lowered to an average of 63 Mm.Hg. by arterial ligations. The number of blows, with two exceptions, was 25 per Kg. of body weight. The amount of swelling was either comparable with or less than that found in Group 2, and in those experiments in which the ligatures were removed one hour after trauma, there was little additional swelling apparent. This was indicative of early arrest of hemorrhage occurring while the limb pressure was low. The systemic blood pressures were in some instances slightly to moderately reduced, but in no case did shock develop. In those animals sacrificed 1.1 to 3.1 hours after trauma the local fluid loss, with a few exceptions, was less than half that of control Group 1, and was not enough to produce shock. The animals that were allowed to survive were in good condition the following day.

In Group 1 the rapid swelling of the limb and the large amount of local fluid loss (which at necropsy was found to be blood in very large measure) are

evidence that factors other than hemorrhage did not play an important part in the production of shock and death.

In Group 2 the animals were protected from shock through the action of the spinal anesthetic in blocking the vasomotor and (less importantly) motor nerves, lowering the blood pressure and reducing the hemorrhage below a level that produces shock. There was no evidence that blockage of nociceptive stimuli was an important factor in preventing shock.

In Group 3 the trauma was greater than in Group 1, and as the nerves were intact, the flow of nociceptive stimuli should, therefore, have been as great as or greater than in Group 1. Still shock did not develop.

There is no evidence in these experiments of an important action from toxins formed in the damaged tissues since, if present, it should have been manifest in Groups 2 and 3, where the trauma was greater than in Group 1, while in Group 1 the onset of shock was too rapid to have been caused by it.

Swingle, and coworkers, confirmed the work of others that section of the nerves to the limbs or of the spinal cord at T-13/L-1 does not prevent shock from limb trauma. This would preclude the possibility that any protection obtained from procaine injections of the nerves or tissues was the result of blockage of nociceptive stimuli from the traumatized regions.

The theory that the descending tracts of the ventromesial areas of the cord protect against limb trauma shock but that afferent nociceptive stimuli from the legs, apparently transmitted by the ventrolateral cord regions, eliminate this factor and sensitize to shock, was tested experimentally as follows: The left dorsal spinal nerve roots below T-12 were sectioned, which destroyed all afferent impulses from the left limb. When the limb was subsequently traumatized there was no sign of protection against shock, as the animals tolerated blood loss and tissue damage no better than did the normal dogs of Group 1.

CONCLUSIONS

1. No evidence was obtained from these limb trauma experiments that either a flow of nociceptive stimuli from the injured field or toxin formation is an important contributing factor in the initiation of any circulatory impairment or shock which followed.

2. The animals in which the trauma was applied soon after the administration of a spinal anesthetic were protected from shock principally by the blockage of the vasomotor and (less importantly) motor nerves, which greatly lowered the blood pressure and limited the hemorrhage to an amount that was too small to produce shock, instead of by the blockage of afferent impulses. The maintenance of such a low blood pressure by spinal anesthesia for the prevention of shock during an operation on man is contraindicated as the amount of anesthetic required would be too toxic.

3. In all of the experiments where shock developed the local blood loss was large and constituted the outstanding causative factor.

4. There appears to be no indication for the renewal of efforts to prevent shock by the blockage of afferent nerve impulses through the use of local

or spinal anesthesia. Indications for the use of local or spinal anesthesia in shock are based on other grounds.

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STAINLESS STEEL WIRE-MESH IN THE REPAIR OF SMALL CRANIAL DEFECTS*

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SMALL CRANIAL DEFECTS, those ranging in size from bur holes to openings of approximately two inches in diameter, have excited little attention in the past but rather have been shrugged off as of no serious consequence. Yet bur holes in the frontal region uniformly result in unsightly depressions

FIG. 1.—Stainless steel wire-mesh (0.0075-inch wire, 28 × 28 count) used to repair a defect in the skull of a dog.

and may be associated with tenderness, especially when filaments of the supra-orbital nerve pass over them. Defects larger than bur holes, but generally less than two inches in diameter, are usually the result of trauma or of small craniectomies, such as are performed for tumors of the skull or drainage of an abscess of the brain. Unless these defects are in the

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forehead they generally constitute no cosmetic problem. At any site, however, they may be tender or spontaneously painful; the pulsation frequently is an annoyance to the patient and the justified fear of injury to "the soft spot" in the head is a constant source of worry.

Bur holes in the frontal region have been filled with bone dust or by buttons removed with the trephine, but these bits of bone absorb rapidly and so fail in the purpose for which they are used. Some, including this

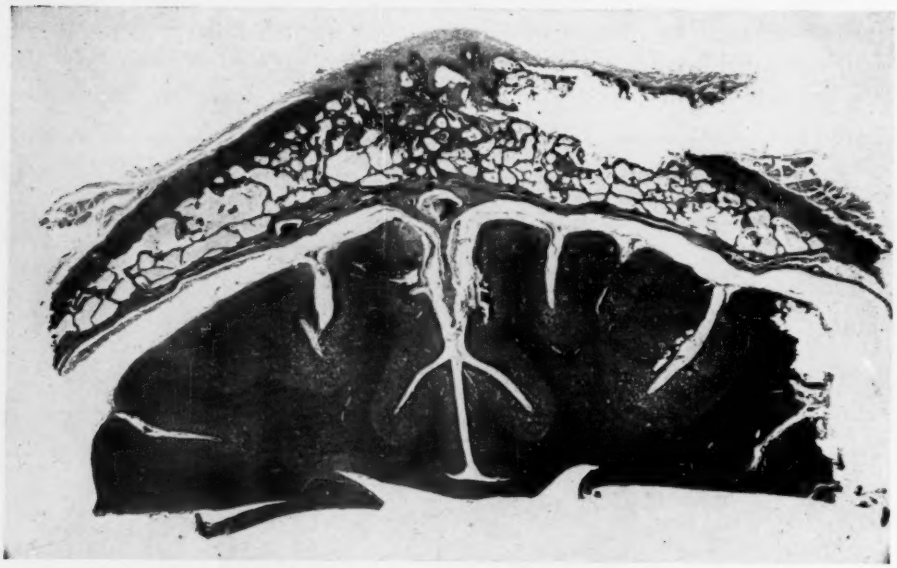

FIG. 2.—Cross-section through the repaired defect in the skull. The mesh was laid on the outer surface of the dura and of the skull. No evidence of irritation of the meninges or brain could be seen. The demonstrable proliferation of bone between the two layers of screen is regarded as being peculiar to the dog.

writer, have regarded the use of bone fragments and dust as actively contraindicated because of the frequence of associated infection.

Slightly larger defects have excited still less attention. In those which follow trauma it has been the custom to replace larger bone chips which, because of their size, are more likely to develop an adequate blood supply, unite with the skull, and prove satisfactory. Other openings of small size have seldom seemed to justify the use of vitallium, tantalum or lucite, which have seen such increasing use in the larger and more surgically attractive group of deficiencies in the skull. Virtually, the small openings have been ignored as necessary evils.

Stainless steel wire has long been recognized as an inert substance in tissues. In the skull it does not show the disadvantages attributed to it when it is used for orthopedic purposes in other bones of the body. Wire used to hold osteoplastic bone flaps in position or in myoplastic craniotomies becomes tightly embedded within the bone as osseous repair takes place. It seemed reasonable that a mesh of stainless steel wire could become anchored in connective tissue and possibly in bone at the edges of a cranial defect.

Likewise, the projection of strands of connective tissue into the meshes of the screen, further strengthening and stabilizing the repair, seemed probable. Accordingly, in March, 1942, the Pilling Company made up, on request, strips of stainless steel wire screen with 0.0065-inch wire (40 x 40 and 70 x 70 count) and 0.0075-inch wire (60 x 60 and 28 x 28 count).

FIG. 3.—Epidural and epicranial layers of screen covering a bur hole in the exposed frontal region.

The mesh was tried first in large dogs. A midline craniectomy was performed, extending from the frontal sinus to a point proximal to the occipital protuberance and about 2.5 cm. on either side of the midline. A layer of screen was then placed against the dura, being held in place against the bone by the force of intracranial pressure. A second layer was placed outside of the skull and fastened with sutures to the adjacent periosteum. The postoperative course of all dogs was satisfactory. After periods of from five to eight months the animals were sacrificed. The edges of all strips were firmly bound to bone by connective tissue. Connective tissue had not penetrated the meshes of the two high-count screens, however, and these did not seem to be so firm as were the repairs utilizing the lower-count screens. The latter had been freely penetrated by connective tissue (Fig. 1) and, when tapped with an instrument, sounded almost as firm as if they were part of the skull. Subsequently, this was proved to be caused in large

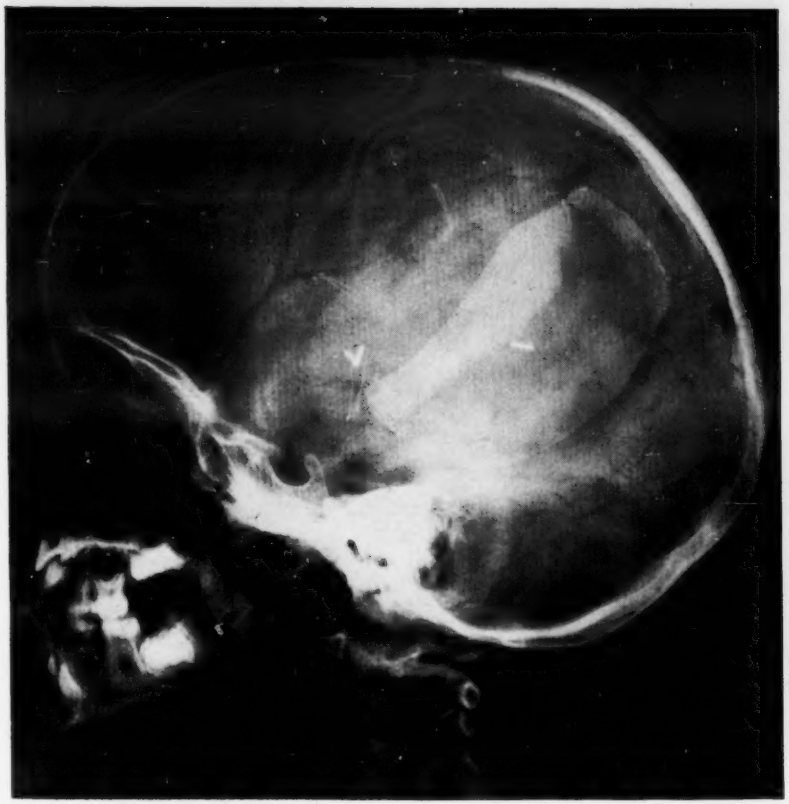

FIG. 4.—Single epidural layer of mesh repairing a posttraumatic defect in a child, age 2. Clinical demonstration of the defect was not possible one year after repair.

FIG. 5.—Repair by single epidural mesh of defect resulting from removal of a tumor of the skull.

part by the spread of bony tissue between the two layers of metal. Cross-section through brain, meninges, calvarium and screen showed but slight dural thickening, no adhesions, no change in the sagittal sinus and no evidence of any harmful effect upon the brain (Fig. 2).

Accordingly, the use of both the 0.0065-inch (40 x 40) and 0.0075-inch (28 x 28) screen was begun in patients. During the past 18 months it has been used for small defects as outlined and has been regarded as satisfactory. No ill effects referable to it have been seen or reported. None of these patients has died, or has required further surgery in the same region, so that no human pathologic material is available. In general, the finer wire and mesh have seemed easier to work with, and more promising in result than has the coarser type.

The size of the piece is determined by direct measurement at the operating table. It is cut from a large strip with heavy curved surgical scissors kept for this purpose. The mesh should be held away from the field while being tailored so that bits of wire will not fall into the wound to act as a potential source of irritation. When used to cover frontal bur holes, a layer of screen is placed between the dura and skull before the bone flap is replaced. This remains in position without sutures. Another piece is added outside the skull (Fig. 3), as the double mesh seems to give a better cosmetic result.

In the repair of the larger openings resulting from trauma (Fig. 4), drainage of an abscess or the removal of a tumor of the skull (Fig. 5), the screen has been slipped through notches in the edge of the bony defect into a position between the dura and the skull, or has been placed over the outside of the opening where it is anchored by sutures of cotton, silk or wire to the adjoining pericranium. Care must be maintained that the edges of the mesh outside of the skull do not stick up to irritate the scalp. A single layer of the wire screen has resulted in a firm, painless support for the scalp, which compares favorably with that offered by adjacent bone. When the cosmetic result is a factor, however, a layer of mesh inside and outside of the skull is more likely to preserve a satisfactory contour.

Within its limitations, therefore, this mesh appears to offer a safe, adaptable and readily available method of dealing with small cranial defects.

FRACTURE OF THE ATLAS

REVIEW AND PRESENTATION OF DATA ON EIGHT CASES

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FRACTURES OF THE ATLAS are notable as regards their apparent rarity of occurrence and their comparatively favorable prognosis. Hatchette[1] noted 99 cases reported to 1941, and added one of his own. Crooks and Birkett[2] have since reported four cases. Eight cases have been encountered at the Mayo Clinic, bringing the total to 112. In 50 of these the lesion has been an isolated fracture of the atlas and in 62 it has been complicated by other injuries, such as fractures of the vertebrae or the skull. It is reasonable to suspect that these fractures are more numerous than these figures indicate but are overlooked because of the erroneous impression that the outcome of the fracture of the atlas is quickly fatal; the mortality rate of 10.7 per cent in the cases reviewed to date establishes this entity as dangerous but by no means necessarily fatal.

Jefferson[3] noted that these fractures are almost always due to trauma to the top of the head when the spinal column is fixed in a neutral position. If the spinal column is flexed or hyperextended the injury occurs in areas of mobility, usually the lower cervical or the thoracolumbar region. Causes of such injuries have usually been falls or blows on the head[4]; accidents in fast-moving vehicles may also produce this picture, as has been pointed out by Plaut.[5] In a few of the cases summarized by Jefferson[6] the fracture was due to direct trauma on the back of the neck. The infrequency of this mechanism may be explained by the excellent protection given the atlas by the overlying skull and mandible, by the protruding spinous process of the axis and by the thickness of the soft tissue of the back of the neck. In one case reported by Crooks and Birkett[2] and in one of our cases, fracture was due to sudden twisting of the neck while swimming under water.

A general knowledge of the anatomy of the atlas is essential for an understanding of the nature of the fracture and its prognosis. The atlas is merely a ring of bone, its centrum having migrated to form the odontoid process of the axis. Its superior and inferior articular facets face obliquely so that the lateral masses are wedge-shaped with their bases lateral. Thus, any compression force on the bone tends to cause it to spread outward, this being resisted by the anterior and posterior arches and the transverse ligament. If the force is too great the ring breaks, usually in the posterior arch as (1) this is weakened by the grooves for the vertebral arteries; and (2) the posterior and lateral facing of the occipital condyles tends to splay the

atlas out in those directions (Fig. 1*a*). Thus the fracture produces a widening of the arch resulting in a decompression of the spinal cord in this area.

Clinical signs are scarce in cases of isolated fracture of the atlas. Ordinarily they consist in pain and stiffness of the neck with tenderness, especially in the suboccipital area. Motions are usually limited and slowly performed, though there may be instability causing the patient to hold his head with his hands.[7] Occasionally the patient may complain of tingling

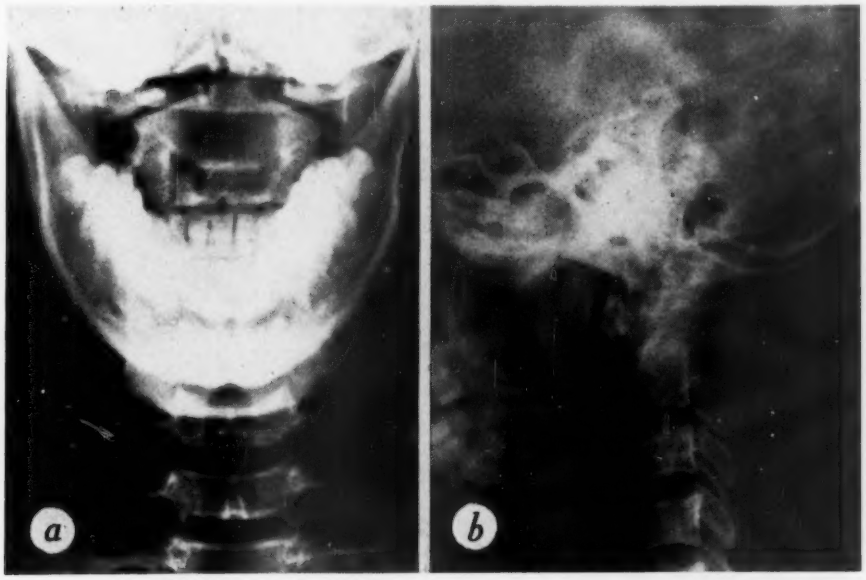

FIG. 1.—*a*. Anteroposterior view showing lateral displacement of both lateral masses of the atlas. *b*. Lateral view showing fracture of both the anterior and the posterior arch of the atlas.

and pain in the arms and legs despite absence of neurologic findings. Swallowing may be painful or impaired because of retropharyngeal hemorrhage, particularly in cases of fracture of the anterior arch. Involvement of the greater occipital nerve may produce neuralgia over its area of distribution. Injury to a vertebral artery occurs in rare instances.

In approximately 85 per cent of the cases one or both arches are fractured. Plaut[8, 9] has reviewed in detail the roentgenographic studies of these fractures. The lateral view readily demonstrates fractures of the posterior arch (Figs. 1*b*, 2 and 3) and may show a displaced fragment of the anterior arch (Fig. 4). The anteroposterior view may show a gap in the anterior arch as well as an outward displacement of the lateral masses (Fig. 1*a*). Fractures of the lateral masses are rare, only eight cases in all having been reported. Even more rare are fractures of the transverse processes; the only reason that these are of clinical interest is that the fragments may injure a vertebral artery. There are other roentgenologic signs of significance. Swelling of soft tissue in the prevertebral space may mean fracture of the anterior arch[10]; an increase of the distance between the anterior arch and

the odontoid process may indicate rupture of the transverse ligament or dislocation.

It may occasionally be difficult to rule out a congenital anomaly of the atlas. Brown[11] reported a case of complete absence of the posterior arch. Lawrence and Anderson[12] and Plaut[13] reported a case of an anomaly of the posterior arch simulating a fracture and discussed differential diagnosis. They noted a defect of one-half inch (1.3 cm.) on each side between the pos-

FIG. 2.—Lateral view showing fracture and separation of the posterior arch of the atlas.

terior arch and lateral masses; the posterior arch was in its normal position, the margins of the defect were smooth and there were neither small fragments of bone nor callus formation in the gap. The infrequency of such anomalies permits them to be only rarely a source of confusion.

Associated injuries frequently, in themselves, produce such overshadowing symptoms and signs that a fracture of the atlas may be overlooked and often they require immediate attention because of their own serious import. In cases of such injuries the possibility of a fracture of the atlas should be kept in mind. They most commonly include fractures of the odontoid process, of other cervical vertebrae and of the skull. Complications most often encountered with fracture of the atlas are rotary subluxation, neuralgia of the greater occipital nerve and rupture of a vertebral artery—the vertebral groove having already been mentioned as a frequent site of fracture. Transient pain and tingling in the arms and legs may be due to jamming of the medulla or cord; actual traumatic myelitis is rare.

The differential diagnosis is not usually difficult. Congenital anomalies have already been discussed. Infections of the atlas are rare and are usually

of syphilitic or tuberculous type; they can be differentiated by history, general examination and laboratory and roentgenographic findings. This is true also of metastatic carcinoma. Arthritis of the upper cervical vertebrae may at times be indistinguishable from an old fracture, particularly if a history of injury is elicited. Roentgenographic studies of the atlas should be made in cases of occipital neuralgia, particularly those in which there is any history of trauma.[14]

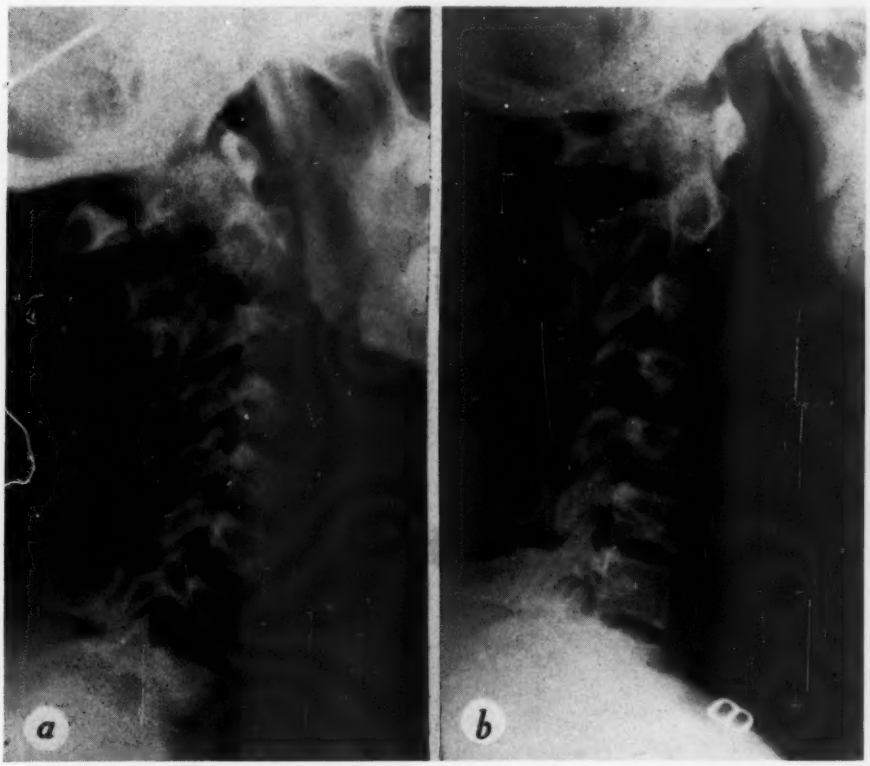

FIG. 3.—*a*. Lateral view showing fracture of the posterior arch of the atlas and of the laminae of the second cervical vertebra and dislocation of the bodies of the second and third cervical vertebrae. *b*. Three months later, showing some callus formation of the posterior arch of the atlas and partial reduction of the second cervical vertebra.

Treatment of fractures of the atlas has become fairly well standardized; good results have been obtained with most means used. Four to six pounds (1.8 to 2.7 Kg.) of head traction in bed, in straight extension, is usually sufficient for immediate relief of symptoms, though occasionally more is needed. A Sayre sling will suffice for this. Relaxation of neck muscles is quickly obtained and in a few days a plaster encasement or a leather collar may be applied to immobilize the neck. Should the fracture be complicated by a tendency to subluxate, the traction may have to be continued for three to four weeks before use of a collar. Six to eight weeks after uncomplicated injury the patient is reëxamined and new roentgenograms are taken. The collar is discarded at any time from eight weeks to four months, depending

on the progress of the patient and the roentgenographic findings. After removal of the collar, return of function is materially aided by physical therapy. Stiffness and limited motion of the neck are stubborn residua of such injuries. Though it may require some months, ultimate return of function is almost always complete. When complicated by greater occipital neuralgia, however, persistent pain may require surgical intervention. Lack

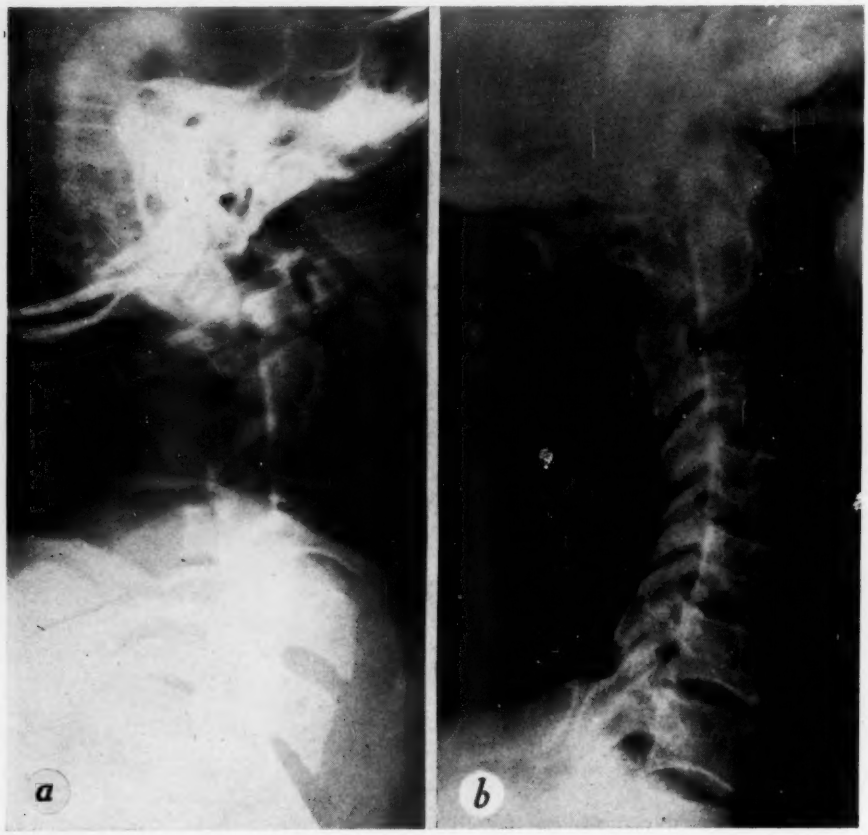

FIG. 4.—*a*. Lateral view showing comminuted fractures with displacement of the anterior and posterior arches of the atlas. *b*. Two and one-half months later. Position slightly improved and some callus formation.

of callus formation is characteristic (Figs. 3*b* and 4*b*), delayed or incomplete union occurring regularly and nonunion frequently.

Data on the eight cases encountered at the Mayo Clinic are summarized in Table I. The patients were evenly divided as to sex; ages ranged from 16 to 63 years. Trauma consisted of falls on head, blows on head, collisions and twisting of the neck under water as previously mentioned. There were six isolated fractures of the atlas; in one case a fracture of the second right rib was associated, and in the other a fracture of the laminae of the axis with a dislocation of the axis forward on the third cervical vertebra. The posterior arch alone was fractured in five cases, the posterior and anterior

arches were fractured in two and the articular facet was fractured in the remaining case. Treatment included various combinations of traction, rest in bed, encasement and collars are shown in Table I.

Results were classed as excellent if there was no limitation of motion of the neck, grating, pain or other disability and in three cases the results are so reported. Good results include one patient who noted slight limitation of rotation to the right and one patient who noted some limitation in rotation to both right and left. In two cases the results are classed as fair. In both of these there were slight tenderness to pressure over the back of the neck

TABLE I

DATA IN CASES OF FRACTURE OF THE ATLAS

Case	Age, Years	Sex	Trauma	Fracture Site	Complications	Therapy	Results and Time
1	48	F	Turned head while under water	Articular facet	None	Collar	Excellent 12 years
2	16	F	Dived into shallow water, hit top of head	Anterior and posterior arches	None	Traction and encasement	Excellent 14 years
3	35	M	Train collision	Posterior arch	None	In bed, encasement	Good 22 years
4	58	F	Car collision	Posterior arch	None	Kept in bed	Good 23 years
5	28	M	Fell 55 feet (17 meters)	Posterior arch	None	In bed, encasement	Fair 16 months
6	63	M	Fell off load of hay on head	Posterior arch	None	Traction, encasement	Poor 16 months
7	21	F	Car collision	Posterior arch	Fractured laminae of axis; dislocated axis anteriorly on third cervical vertebra	Traction, collar	Excellent 7 years
8	58	M	Fell 20 feet (6 meters)	Anterior and posterior arches	Fractured second right rib	Traction, encasement, collar	Fair 16 months

and limited rotation 16 months after injury; no further follow-up could be obtained. One patient complained of pain, grating and 50 per cent limitation of motion 16 months after injury and the result is classified as poor. It should be pointed out that the fair and poor results are in cases in which the follow-up is 16 months. With continued use, physical therapy and time, these patients may be expected to improve. There were no deaths in this group.

SUMMARY

Fractures of the atlas have been discussed and data on eight additional cases presented. This type of fracture is dangerous but not necessarily fatal. It probably occurs more frequently than has been reported but is overlooked. The usual treatment consists of traction followed by application of a plaster encasement or a leather collar. In three cases the results were classed as excellent, in two, as good, in two, as fair and in one case as poor. These fractures rarely unite but there is rarely any ultimate disability, although stiffness and limited motion of the neck may persist for several months.

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CHEST WOUNDS IN BATTLE CASUALTIES

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IN A PERIOD of approximately nine weeks during the campaign in France and Belgium, an Evacuation Hospital gave surgical treatment to 5,124 patients, nearly all of whom were battle casualties. One hundred and fifty-seven, or 3 per cent, of these patients had wounds of the chest cavity. There were 25 deaths, a mortality of 15.9 per cent. Six casualties, who died before reaching the operating room, are not included in this report.

In the 1914–1918 war, there were 4,595 cases of thoracic injuries among the American casualties, with a mortality of 24.05 per cent.[1] Gordon-Watson[2] states that the total mortality for chest wounds in the British Army in France, during the same war, was 27.5 per cent, and Brunner[3] states that 2.6 per cent of all German casualties who reached casualty clearing stations had chest wounds. Holman[4] estimates the mortality of chest cavity wounds, in the Pacific combat area, during this war, to be approximately 40 per cent.

Simple Hemothorax.—Forty-five casualties had relatively minor penetrating wounds which caused simple hemothorax and required no treatment other than aspiration.[5, 6] In 12 of the 45 cases, the hemothorax was small and caused no respiratory distress; these casualties were evacuated without aspiration.

One patient, a prisoner of war, with a simple hemothorax died following a débridement of minor chest wall and arm wounds under sodium pentothal anesthesia. This patient had 800 cc. of blood removed from the pleural cavity on admission; and a roentgenogram of the chest ten hours later revealed only a small amount of fluid. Immediately after operation, the patient developed acute respiratory distress and died within an hour. Autopsy showed the left chest to be filled with blood. It was not determined whether the bleeding had come from the lung or from an intercostal vessel. Whatever the source, it was presumed that the bleeding which had temporarily stopped was reactivated by the operative procedure.

Penetrating Wounds—Not Sucking.—Forty casualties had penetrating wounds, not of the sucking type, with damage to the chest wall of such extent that serious injury to the lung was suspected. Limited thoracotomy was done in these cases, the chest being opened through the wound of entrance. In 23, a laceration of the underlying lung was found and sutured. The one death in this group occurred during the operation, when the lung was temporarily allowed to collapse to facilitate exploration of the chest cavity. The heart stopped suddenly and without warning, and all efforts to restore action were without avail.

Sucking Wounds.—Thirty casualties reached the operating room with sucking wounds, but in every case the sucking had been temporarily controlled,

though not always completely, by dressings A lacerated lung was found in 14 of these cases. The wounds of the chest wall were treated by a débridement, which included resection of all fractured rib ends. The opening in the chest cavity was then made large enough to allow satisfactory inspection of the lung and pleural cavity.[7] Any lacerations found were sutured. No difficulty was encountered in closing the defect in the chest wall. In this group of 30 cases there were ten deaths, a mortality of 33.3 per cent. Gordon-Watson[2] in a review of 3,521 penetrating wounds of the chest, gives the mortality of sucking wounds as 44.6 per cent.

Deaths.—1. The first death occurred in a soldier who had lost a large amount of blood and, at operation, was found to be bleeding from an intercostal vessel and a lacerated lung. The bleeding was controlled without difficulty, but only two pints of blood were available at the time to replace the massive blood loss. This amount was inadequate and, although he received continuous plasma and saline infusions, the patient died one hour after completion of the operation.

2. The second death occurred in a casualty who had a sucking wound and extensive damage to the lower lobe of the left lung. The lung was sutured and the chest wall closed. This patient died on the third postoperative day. Autopsy revealed a large amount of interstitial hemorrhage in the left lung but otherwise no satisfactory explanation as to the cause of death.

3. The third death occurred in a soldier with a sucking wound of the left chest and a laceration of the lung. He did not fully react following the operation, and died about eight hours after leaving the operating room. He had marked respiratory distress for which no adequate explanation was found at autopsy. There was a large congenital hernia of the left diaphragm which contained a part of the stomach, and this may very well have been a factor in the production of respiratory embarrassment.

4. The fourth death occurred in a soldier with two small sucking wounds of the left chest which were closed under local anesthesia. In this case, there was no laceration of the lung. This patient's major wound was a fractured jaw which bled freely and blood had been aspirated into the lungs. The patient developed a pneumonia which proved fatal on the first postoperative day.

5. The fifth death occurred in a soldier with a sucking wound of the right chest and a transection of the spinal cord at the level of the 11th thoracic vertebra caused by the same bullet. The patient died from pneumonia on the first postoperative day.

6. The sixth death occurred in a soldier with a sucking chest wound and a partial transection of the spinal cord at the level of the 4th thoracic vertebra. The sucking wound was closed and a laminectomy was done to explore the spinal cord. Death was caused by pneumonia.

7. The seventh death occurred in a prisoner of war with a sucking wound of the chest and a large laceration of the lung. The patient

died on the first postoperative day. Autopsy revealed an extensive bronchopneumonia throughout both lungs.

8. The eighth death occurred in a soldier with a deep and irregular laceration of the right lung. This patient developed pulmonary edema and died on the first postoperative day. At autopsy, the damaged lung was found to be consolidated with blood which filled the bronchioles, alveoli, and interstitial spaces.

9. The ninth death occurred in an officer with an extensive wound of the chest wall and multiple deep lacerations of the lung, which were sutured with some difficulty. The patient died on the third postoperative day and, as in the preceding case, the principal finding at autopsy was a heavy consolidated lung filled with blood.

10. The tenth death occurred in a soldier with a large sucking wound of the right anterior chest and a complete fracture through the lower third of the sternum. There was little improvement in the patient's respiratory distress following closure of the wound. The mechanical difficulty of adequate respiration with a mobile lower sternum appeared to be the cause of death.

Tension Pneumothorax.—Three patients were operated upon because of persistent tension pneumothorax. One had had his initial treatment at a Field Hospital, where a sucking wound had been closed. He was in acute respiratory distress on admission to the Evacuation Hospital two days later; and the right chest cavity was filled with air under pressure. At operation, a laceration of the right lower lobe was found from which air escaped with each respiration. The lung was sutured and the patient recovered.

The second tension pneumothorax occurred in a patient to whom we had given the primary treatment. There was an unrecognized depression of a fractured rib which caused a laceration of the lung, with resulting tension pneumothorax. The patient was returned to the operating room and the fractured rib ends were resected and the laceration of the lung sutured, following which the patient made an uneventful recovery.

The third tension pneumothorax occurred in a soldier who had had a sucking wound of the left chest closed at a Field Hospital three days before, and was in acute respiratory distress upon admission to our hospital. A thoracotomy was done, and the left lung was found collapsed. A laceration was sutured and the lung expanded, but the patient died at the end of the operation. Autopsy revealed considerable pneumonia in the lung of the opposite side.

Secondary Hemorrhage.—One casualty developed a secondary hemorrhage ten days after being wounded. In this soldier, a bullet had entered the left shoulder, traversed the lung, and lodged in the 10th thoracic vertebra, causing a paraplegia. Although a fairly large hemothorax was present, it caused few symptoms, and was easily controlled by aspiration. Because of an alarming hemorrhage which occurred on the tenth hospital day, a thoracotomy was done. To control the bleeding, it was necessary to place a tourniquet around the hilus of the lung. The patient's condition was poor,

but there appeared to be no way to control the hemorrhage except by pneumonectomy. This was done, and he made a satisfactory recovery. Two weeks after operation he was transferred to a General Hospital, and a report ten days later stated that his condition was good. There was, however, no improvement in the paraplegia.

Thoraco-abdominal Wounds.—There were 36 patients in this group. One patient died during the induction of anesthesia, and only 35 were actually operated upon.

Nineteen of the thoraco-abdominal wounds were on the right side and 17 on the left. In 11 cases it was possible to do an adequate, but not complete, abdominal exploration by enlarging the thoracotomy incision. When a complete abdominal exploration was needed, a celiotomy incision was necessary. The patients who had the chest pathology corrected prior to celiotomy did much better than those who had a celiotomy first. There were 11 deaths in this group, one preoperative and ten postoperative. In eight of these, death appeared to be due primarily to the abdominal injuries. One patient in the group died of an associated head injury.

Deaths.—1. The first death occurred in a soldier with a penetrating wound over the liver and a small wound of the right chest caused by separate shell fragments. The operation was undertaken because of the injury to the liver and no operation on the chest was contemplated. This patient died during the induction of anesthesia and in addition to the laceration of the liver. Autopsy revealed a small hemothorax. There was no injury to the diaphragm and it is questionable whether this case should be included with the thoraco-abdominal wounds.

2. The second death occurred in an officer with a sucking wound of the left chest and an extensive laceration of the left kidney. The chest wound was closed and the kidney removed through an abdominal incision. This patient died on the seventh postoperative day of renal failure, with uremia. Autopsy revealed an atrophic, nonfunctioning right kidney.

3. The third death occurred in an officer who had severe wounds of the chest and abdomen. Through an abdominal incision, a laceration of the liver was sutured, and perforations of the stomach and colon closed. The chest wound, which was not the sucking type, was débrided and closed. This officer died on the fifth postoperative day. Autopsy revealed a large amount of blood in the pericardium although no penetrating wound of the pericardium or heart could be demonstrated. Some degree of tamponade had undoubtedly occurred, and it was felt that this was the primary cause of death.

4. The fourth death occurred in a soldier with a sucking chest wound and severe lacerations of the kidney and spleen. The patient was almost exsanguinated on admission to the shock ward. Operation was undertaken to control the bleeding but the shock was irreversible, and the patient died 12 hours after removal of the spleen and kidney.

5. The fifth death occurred in a soldier with a minor chest wound but with multiple perforations of the stomach, colon, and small bowel. At opera-

tion, the peritoneal cavity was found to be filled with blood and intestinal contents. Death occurred on the day of operation due to shock and peritoneal infection.

6. The sixth death occurred in an officer with a large sucking wound of the chest, a perforation of the stomach, and a compound fracture of the humerus. The chest wound was closed and the fractured arm immobilized, but the patient continued in such poor condition that a celiotomy could not be undertaken. He died of shock and peritonitis.

7. The seventh death occurred in a soldier with a sucking chest wound and a severely lacerated liver. The chest wound was closed, and the liver packed through an abdominal incision. This controlled the bleeding but the patient died from shock on the first postoperative day.

8. The eighth death occurred in a soldier with a severe penetrating wound of the skull, a perforation of the colon, and a small sucking chest wound. All these wounds were given surgical treatment and the patient sent to the ward in fair condition. He died one week later from the intracranial injury.

9. The ninth death occurred in a soldier with a small chest wound, a laceration of the stomach and multiple perforations of the small bowel. Death was due to peritonitis.

10. The tenth death occurred in a prisoner of war, with a small sucking wound of the chest, lacerations of the spleen and kidney, a transection of the colon and multiple perforations of the small bowel. This patient died on the second postoperative day of shock.

11. The eleventh death occurred in a soldier with a large sucking wound of the chest and perforations of the small bowel. Closure of the sucking wound did not improve the patient's condition enough to permit celiotomy and he died of shock and peritonitis the day after admission.

Wounds of the Heart and Pericardium.—Four patients were found to have wounds of the heart or pericardium. Two of the patients had lacerations of the pericardium without any damage to the heart. These lacerations were partially sutured and left so that the pericardial and pleural spaces were continuous. Both patients made uncomplicated recoveries. A third patient was found to have an hemopericardium of about 200 cc. in addition to a sucking chest wound. The hemopericardium was suspected prior to operation as a splash could be heard with each heart beat. A small incision was made in the pericardium and the blood evacuated. The bleeding apparently had stopped, and its source was not obvious. The patient made a good recovery. A fourth patient with a sucking chest wound was found to have a laceration of the left ventricle. This patient died of hemorrhage as an attempt was being made to suture the laceration.

Crush Injury of the Chest.—There was one crush injury in the series. This was caused by the wheel of a 2.5-ton truck passing over a soldier's chest, fracturing five ribs along the right anterior axillary line. The pain was so severe that breathing was entirely diaphragmatic, and a moderate degree of cyanosis was present. Under local anesthesia, the ends of the fractured ribs

were resected, and under one of the fractures a small tear in the pleura was found. Following operation, there was definite improvement in the respiration, and the soldier made an uneventful recovery.

Infection.—All penetrating wounds of the chest wall, with a single exception were débrided, treated with penicillin and sulfanilamide, and completely sutured. In addition to local sulfanilamide and penicillin powder, all chest casualties received one gram of sulfadiazine every four hours by mouth, usually for a period of about seven days, and 20,000 units of penicillin intramuscularly every four hours for 48 hours. There were no wound infections and no infection of the pleural cavity during the period of observation, which was ten days to two weeks.

The one wound not completely sutured was in a prisoner of war whose wounds were two days old on admission, and badly infected. There were multiple wounds of the chest wall, two had penetrated the chest cavity, and one shell fragment had perforated the diaphragm. In this case, the wounds of the chest wall were débrided and the muscular layer closed, but the skin was left open. The pleural and peritoneal cavities were grossly contaminated but they did not at any time present evidence of an active infection. The patient was evacuated on his tenth postoperative day in excellent condition.

Foreign Bodies.—No patients were subjected to operation solely because of the presence of a foreign body in the chest cavity.[7, 9] In eight cases, however, foreign bodies were removed, six were in the periphery of the lung and two were free in the pleural cavity.

Drainage of Chest Wounds.—The pleural cavity was not drained following any of the 111 operative procedures. One or more aspirations were usually needed before the patient was evacuated. One patient, with a thoraco-abdominal wound of the right side, collected a large amount of bile in the right chest. This was controlled by daily aspiration, and the drainage had almost stopped when the patient was evacuated on his twelfth postoperative day.

CONCLUSIONS

Experience based upon the relatively small number of cases in each group does not justify fixed conclusions as to treatment but does offer suggestions.

1. Small penetrating wounds of the chest cavity causing simple hemothorax are best treated by aspiration alone.

2. Penetrating wounds of the chest cavity, with fractured ribs or suspected injury to the lung, should have a limited thoracotomy through the wound of entrance or exit. The fractured rib ends should be resected, the blood evacuated, and the lacerations of the lung sutured.

3. In treating sucking wounds of the chest, an incision large enough to allow inspection of the lung is usually indicated because of the probability of lung injury. A laceration which leaks air or bleeds is often found and should be sutured.

4. Thoraco-abdominal wounds are usually best handled by two incisions.

TABLE I

		Deaths	Mortality
Wounds of chest cavity	157	25	15.9%
Operative procedures	111	24	21.7%
Simple hemothorax	45	1	2.2%
Penetrating wounds	40	1	2.5%
Tucking wounds	30	10	33.3%
Thoraco-abdominal wounds	36	11	30.5%
Wounds of heart and pericardium	4	1	25.0%
Crush injury	1	0	0
Sension pneumothorax	3	1	33.3%
Secondary hemorrhage	1	0	0

In 23, or 57.5 per cent, of the penetrating wounds, and in 14, or 46.6 per cent, of the sucking wounds, lacerations of the lung were found and sutured.

Three patients with wounds of the heart and pericardium are also classified with the sucking wounds.

Two patients developed tension pneumothorax after closure of sucking wounds, and in the third, tension pneumothorax developed in a patient with a penetrating injury which had fractured and depressed a rib. Classified separately for emphasis.

In most cases, the thoracotomy should be done first and then the celiotomy.

5. The ends of fractured ribs, particularly when it is suspected that a piece of rib may penetrate the pleura, should be resected. Local anesthesia is the anesthesia of choice for this procedure.

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THE PROBLEM OF MASSIVE HEMORRHAGE FROM DUODENAL ULCERS OF PATIENTS BEYOND MIDDLE LIFE

WITH PARTICULAR REFERENCE TO THE VALUE OF THE DEVINE EXCLUSION OPERATION IN SELECTED CASES OF THIS NATURE

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CONSIDERING both the acute massive and the chronic types of hemorrhage, most authors are agreed that about 25 per cent of patients suffering from duodenal ulcer are subject to this complication. In cases in which the patients are less than 45 years of age, it is a serious but usually not fatal complication, for conservative measures usually suffice to control the bleeding. However, if the patient is 45 years of age, or more, this bleeding becomes much more ominous. Allen and Benedict,[2] Bohrer,[3] Westermann,[9] and many others, have emphasized that half of these older patients beyond age 50, who have bled have had the massive type of hemorrhage and that about a third of these patients will die of hemorrhage if treated conservatively and supportively.

Whether or not surgical treatment is logical for this 33 per cent of patients more than fifty years of age who may die otherwise is still hotly contested and a tremendous literature has grown up about the subject. As greater numbers of these patients are operated upon, and as surgical technic and postoperative care are perfected, those operations giving poor results should be eliminated. Furthermore, the immediate mortality rate should decrease. Walters and Cleveland[8] have compared the risk of partial gastrectomy for bleeding peptic ulcer in 135 cases in the five-year period ending with 1936, with that of 119 cases in which operation was performed in 1940. In the earlier group the mortality rate was 10 per cent, in the latter group, 4 per cent. The time of operation and the type of procedure were found to be important, considering the age and condition of the patient.

Finsterer[6] has urged immediate operation during the acute phase of the bleeding. He reported data on a series of 78 cases in which operation was performed within 48 hours of the massive hemorrhage. Four patients died (5 per cent). Gastric resection was performed in 71 cases and gastroenterostomy in seven. In a series of 74 cases in which operation was not immediate, 22 patients died (30 per cent). Large enough series of such cases still have not been reported to enable one to draw final conclusions.

A decision as to the type of procedure to be performed is difficult to reach. Gastric resection with removal of the hemorrhagic lesion should be the opera-

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tion of choice. In any event, all the mucous membrane of the pyloric antrum should be removed whenever at all possible. In a recent study by us, recurrence of gastrojejunal ulceration or bleeding occurred in from 10 to 16 per cent of cases after the Finsterer type of resection, in about 40 per cent of cases after the Devine exclusion operation and in more than 60 per cent of cases after the Eiselsberg operation, in all of which varying amounts of pyloric antrum are left. Walters and Cleveland reported 92 per cent satisfactory results following partial gastrectomy for bleeding peptic ulcer if the pyloric antrum was removed and if entero-anastomosis was not performed. In the 112 cases followed by these authors there were 15 unsatisfactory results. In four of these 15 (27 per cent), the pyloric sphincter and antrum were not removed. In one of these four cases death occurred from massive hemorrhage four years later. For bleeding duodenal ulcer alone, they reported 94 per cent satisfactory results following partial gastrectomy. Only two of these patients failed to obtain relief from primary gastric resection and in both cases the antrum was not removed.

The importance of removing the pyloric antrum and pyloric sphincter cannot be overemphasized, but it was not until recently that this fact has been appreciated thoroughly. The recent study by us of all types of exclusion operations, whether or not resection was performed, demonstrated this point clearly. The pyloric antrum should be removed to give the patient the best chance of permanent cure. The study, likewise, emphasized, however, that in many cases the condition of the patient is too poor to justify extensive gastric resection and that in many cases the duodenal lesion is the site of too active inflammation, hemorrhage and edema to warrant the extensive dissection necessary to include the antrum. Whether or not the antrum is to be included in the resection in such cases must be decided by the surgeon. Rarely it may happen that not only is the possibility of resecting the antrum remote but the patient is in such poor condition that resection of any kind is foolhardy. This is particularly true of bleeding lesions of elderly patients. Since Finsterer,[6, 7] Allen,[1] and others, have emphasized the necessity of removing at least two-thirds of the stomach if resection is undertaken, removal of lesser amounts of the stomach to decrease the risk in cases in which the patients are very ill gains little. Yet the patients must be protected as well as possible against further hemorrhage. It was this particular problem that led to a further study of the various exclusion operations.

The ideal operation for these elderly patients who have experienced massive hemorrhage should be performed quickly and easily, with as little trauma as possible because of their hemorrhagic tendency. It should allow complete isolation, the exclusion of the ulcer from the gastro-intestinal continuity, since these people, as a rule, are too ill to allow direct attack upon the point of bleeding by the radical expedient of gastric resection. The Devine exclusion operation meets these rquirements, but recurrence of trouble was noted in about 40 per cent of the 62 cases studied by us. It will be noted, however, that only a relatively small percentage of these patients were more than 50 years of age at the time the exclusion operation was done.

Devine[4, 5] first employed his exclusion operation in 1916, and recommended it for use if the patient was a woman, in cases of cicatricial, stenosing ulcer, and in cases in which the lesion was deep on the posterior duodenal wall. He expressed the belief that the number of good results compared favorably with the results of gastric resection, without the risk of the latter. He simply transected the stomach at the angle, though he believed that the closer to the cardia the division was made, the greater the resulting achlorhydria. The pyloric segment was closed and retrocolic, complete, terminolateral gastrojejunostomy was performed. The operation obviously is much quicker and simpler than any resection. The storm of controversy aroused concerning this operation is reflected in the voluminous literature that has accumulated. The consensus of surgeons seems to be that in most cases of duodenal ulcer there is no place for treatment by a Devine exclusion operation.

ANALYSIS OF DATA FROM THE MAYO CLINIC

Data on 62 patients upon whom the Devine exclusion operation was performed at the Mayo Clinic in the 15-year period ending January 1, 1941, form the basis of this particular study. This is the same group of patients followed by us in our study of all exclusion operations performed at the clinic in that period. It may be that the Devine exclusion operation will find its only use in carefully selected cases in which the patients are 50 years of age, or more, have severely bleeding duodenal lesions and are in poor condition for any surgical procedure.

Of these 62 patients, three died in the hospital, a mortality rate of 5 per cent. Only one of the three was more than 50 years of age. He was a 52-year-old man, for whom gastro-enterostomy had been performed years before, because of a severely bleeding duodenal ulcer. He had had at least three episodes of bleeding between the two operations. He was severely anemic and in poor condition at the time of operation. A subacutely inflamed duodenal lesion was found. The patient died seven days after operation as the result of intestinal obstruction. Thirty-six of the entire group (58 per cent) were found at operation to have either a subacute or an hemorrhagic lesion. Seventeen of the group were 50 years of age, or more, and only one (6 per cent) of these died after operation, in spite of the fact that all but two were in poor condition for any operation.

Of the 59 patients who survived operation, 52 were traced carefully. Follow-up studies of patients who have had operations upon the stomach are eminently unsatisfactory. There is no period of years which can be set arbitrarily, beyond which, if the patient has remained well during that period, he may be assured of a permanently good result. As of November 1, 1941, 21 patients (40 per cent) were known to have had further trouble, manifested by hemorrhage, necessitating further operation, or had been proved by roentgenologic examination to have had stomal ulceration. A study of these 21 poor results is interesting.

Eighteen of the 21 patients who had recurrence of trouble were less than

50 years of age. Three only (14 per cent) of this unfortunate group were 50 years of age or more. All three had had acute bleeding, and all had had previous operations for the ulcer. A man, age 59, had had episodes of severe bleeding from a proved duodenal ulcer. At the age of 54 he had had a perforation of a "peptic" ulcer, which was closed simply. His condition was unfavorable for surgical treatment, and at operation it was impossible to perform retrocolic anastomosis of any kind. A Devine exclusion operation and antecolic, complete (Pólya), terminolateral gastrojejunostomy were done. An entero-anastomosis was made. This case has been quoted by Walters and Cleveland also. The patient had a severe hemorrhage within two months, another in eight months, and he died of hemorrhage 15 months after the operation. Walters and Cleveland as a result of study of such cases, have mentioned the inadvisability of performing entero-anastomosis when dealing with a bleeding duodenal lesion.

In the second of these three cases the patient was a woman age 58. She had a history of bleeding duodenal ulcer of many years' duration. Twenty years previously a perforation of the ulcer had been closed. Seven years previously gastro-enterostomy for bleeding duodenal ulcer had been done. At operation, she was observed to have a subacutely inflamed duodenal ulcer with much brawny edema. Her immediate course was good but further trouble developed in six months, and reoperation was performed several times for gastrojejunal ulceration. The patient finally died after one of these operations.

In the third case the result must be listed as poor, although the patient is living and well five years after the Devine exclusion operation. He was a man age 56, and also had a history of acute hemorrhage from a duodenal ulcer. Posterior gastro-enterostomy had been done five years previously but the stoma had been disconnected because of a large gastrojejunal ulcer one year previous to the Devine exclusion. Soon after normal gastro-intestinal continuity had been reëstablished, the ulcer became reactivated and bled on at least one occasion. The patient was in poor condition, being anemic and dehydrated. At operation, it was not thought that he could withstand an extensive procedure and the Devine exclusion operation was performed. He did very well for nearly two years but then returned to the clinic with typical symptoms of a gastrojejunal ulcer, without bleeding. This was proved by roentgenologic examination, and he was sent home on medical management. Three years later, or five years after the exclusion operation, he was much better, did not have any bleeding, and was quite active.

The remaining 31 patients of the 52 traced were found, as of November 1, 1941, to have had either no further trouble or only mild symptoms of indigestion. There was no bleeding, no further operation, and no proved gastrojejunal ulceration. Twenty-one of these patients were considered to have had good results and ten had had only fair results. Since this operation was performed more frequently in the early portion of the 15-year period than later, many of the patients have been followed ten years

or more. Only three (10 per cent) were traced less than three years, while 19 (61 per cent) were followed more than ten years and five (16 per cent) were traced 15 years or more.

As contrasted with the group of poor results, in which only 14 per cent of the patients were 50 years or older, in this group of 31 patients, 13 (42 per cent) were more than 50 years of age. Four of the patients were more than 60 years old. Eight had had episodes of massive hemorrhage, requiring transfusion, or attended by syncope and prostration. Four had had previous operations for the ulcer; two of the four had had multiple previous operations. All but two of these 13 patients were considered to be in poor condition at the time of operation but the risk of operation was thought to be less than the risk of exsanguination. In all, of the 62 patients studied, 17 were 50 years of age or older. One of these died (6 per cent) after operation. Thirteen (81 per cent) of the remaining 16 obtained good results.

The problem is illustrated by the two following reports of cases:

CASE REPORTS

Case 1.—A white, male, farmer, age 53, was admitted to the Mayo Clinic July 25, 1928. He was obviously very ill. His familial history was noncontributory. He had been fairly well until the onset of his present illness and had not had any operations.

The patient complained that for about a year he had been having "stomach trouble." This was manifested by typical postprandial epigastric distress, usually relieved by food, sodium bicarbonate or belching. There was occasional vomiting but none of it was of retention character. The distress had become progressively worse with only short intervals of remission and on two occasions he had noted tarry stools followed by weakness and dizziness. No massive hematemesis was reported. During the six months prior to admission he had noticed extension of the epigastric pain to his back, and had complained of increasing weakness and dizziness.

In addition, the patient had been told 15 years previously, during a life insurance examination, that he had "heart trouble." For five or six years he had noticed exertional dyspnea but had not had any severe precordial pain. Tachycardia and palpitation were occasionally present. No orthopnea or edema of ankles or face had been observed.

On examination, the patient was markedly undernourished and anemic. The lungs were clear but the heart was enlarged, and a loud, rough, blowing systolic murmur was heard at the apex and transmitted to the axilla. There was no sign of myocardial failure. Blood pressure was 120/80, in the lying position. There was slight epigastric tenderness but no mass was felt. The prostate was enlarged and firm, and moderate sclerosis of the peripheral vessels was noted.

Uranalysis showed a small amount of albumin and an occasional leukocyte. The concentration of hemoglobin was only 17 per cent and the erythrocytes numbered 2,270,000. The blood urea value was normal. The flocculation reaction for syphilis was negative. Prostatitis and a small amount of prostatic obstruction were noted. The electrocardiogram showed sinus tachycardia and aberrant QRS complexes. Exaggerated P waves were present in lead II. A roentgenogram of the stomach showed an ulcer, with deformity of the second portion of the duodenum.

The patient's condition obviously was unfavorable for surgical treatment. He was thought to have chronic mitral endocarditis, well compensated. It was felt that he was probably bleeding from a perforating duodenal ulcer, and that operation should be performed.

At operation, August 2, 1928, a large inflammatory mass involving the first part of the duodenum was found. It had perforated into its surrounding omental tissues, with resulting edema and brawniness of these tissues. It was technically impossible to free up the duodenum and a Devine exclusion operation was performed. The stomach was divided at the angle, the pyloric end was closed and retrocolic, complete (Pólya) gastrojejunostomy was done. The postoperative course was not complicated and the patient left the hospital on the fourteenth day after operation.

The patient returned to work within two months and, in answer to an inquiry, seven years later (1935) stated that he had not had any more bleeding. He did not make any complaints referable to his stomach at that time. In June, 1941, 13 years after the operation, he was still well. He still did not have any symptoms referable to the stomach, and had not had any further bleeding.

Case 2.—A male Negro, age 60, was admitted to the clinic, August 11, 1928, complaining of "stomach trouble" of 30 years' duration. His family history was noncontributory. He had not had any serious illnesses or any previous operation.

The "indigestion and stomach trouble" were manifested by periodic attacks of postprandial epigastric distress lasting eight to ten days in the spring and fall, and controlled by food or sodium bicarbonate. The patient had never had adequate medical care. One and one-half years before admission he had had a severe attack during which he may have fainted. One month before being seen at the clinic he had vomited large quantities of coffee-ground material and had fainted. Tarry stools were present for about a week. Peptic ulcer had been diagnosed.

On examination, the man appeared anemic. His pupils reacted sluggishly to light but well to accommodation. There was a slight exudate over the right fundic field. Otherwise, the physical examination gave normal results.

The results of uranalysis were normal except for a few hyaline casts and a small number of leukocytes. The hemoglobin content of the blood was only 27 per cent of normal; and erythrocytes numbered 2,600,000. The flocculation reaction for syphilis was negative. Examination of the right fundus revealed moderate retinitis, probably associated with the anemia. A roentgenogram of the stomach revealed a duodenal ulcer.

At operation, August 16, 1928, a scar of an old ulcer was seen on the anterior duodenal wall. The scar was excised by cautery. This was not thought to be the source of the bleeding. There appeared to be a second lesion deep in the posterior wall of the duodenum, which had perforated onto the pancreas. Because of the repeated hemorrhages and the location of this deep lesion a Devine exclusion operation was performed. The stomach was divided above the angle, the pyloric half was closed and gastro-intestinal continuity was restored by retrocolic complete (Pólya) gastrojejunostomy. The patient contracted pneumonia on the fifth postoperative day but finally recovered.

Since the operation the patient has been heard from on several occasions, last in June, 1941, 13 years after the exclusion operation. At no time has he had further bleeding. He has gained weight, but has multiple minor symptoms, none of which are referable to the stomach.

COMMENT.—After careful evaluation of the history and physical findings of these patients more than 50 years of age, who had bleeding duodenal lesions, it does not seem probable that any of them would have survived extensive gastric resection. Anything less than an extensive resection has been shown to give little better ultimate results than an exclusion operation or gastro-enterostomy. Furthermore, in none of these cases would it have been technically possible, or reasonably safe, to dissect the duodenum free enough to allow transection below the pylorus.

SUMMARY

Ample evidence has been accumulated to emphasize the necessity of resecting the pyloric sphincter and antrum whenever possible in the course of a high gastric resection for duodenal ulcer. There are, however, many instances in which surgical discretion forbids such an ideal procedure: (1) because the duodenal lesion is the site of active inflammation and is surrounded with indurated and edematous tissue; or (2) because the patient himself is in no condition to undergo an extensive resection; or (3) for both reasons. The surgeon then must exercise judgment and perform that operation which seems indicated.

The Devine exclusion operation would seem to have only a limited place in the repertory of treatment for duodenal ulcer. Of a group of 62 patients of all ages, for whom the operation was undertaken, we succeeded in tracing 52. Forty per cent of the traced patients were known to have had recurrence of trouble. However, if the operation is to be performed at all, it would seem indicated only for that small and select group of elderly patients who have bleeding, nonobstructing duodenal lesions and who for various reasons are in poor condition for any type of surgical treatment. Seventeen patients age 50 years, or more, were found to be included in this group of 62. One of these patients died seven days after the operation (6 per cent). Of the remaining 16, only three (14 per cent) were included in the group of 21 who had recurrence of trouble. One of these three has since become well. Thirteen were part of the group of 31 (42 per cent) who obtained good results from the operation. While only 31 (60 per cent) of the 52 patients of all ages whom we succeeded in tracing obtained good results, 13 (81 per cent) of the 16 elderly patients have not had any further trouble. That they survived the operation at all is a good argument for its use in such cases.

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PANCREATICODUODENECTOMY FOR ISLET CARCINOMA*

A FIVE-YEAR FOLLOW-UP

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Case Report.—Unit No. 392089: Mrs. A. C., age 53.

History: The patient was first studied in the Vanderbilt Clinic, in February, 1940, for a complaint of epigastric pain and loss of weight and strength of two month's duration. Her past history, except for three similar attacks 23, 12 and 5 years ago, was irrelevant. During the previous two months, as a result of excessive work, she had developed a severe burning epigastric pain, with acid eructations, relieved by alkalies and small feedings of bland food. During this time she had lost 12 pounds, and had an admission weight of 80.25 pounds. She was admitted to the Medical Service.

Physical Examination: The patient was a tired, thin woman, looking chronically ill, not anemic or jaundiced. The only positive findings were in the abdomen. There was epigastric tenderness, high up near left costal margin and below and to the right, just above the umbilicus, could be felt a firm, nontender movable mass, four centimeters in diameter.

Laboratory Data: Hb. 11/7 Gm., R. B. C. 4,100,000; normal white cell count and differential. Gastric analysis: Free HCl—O, 20 minutes after histamine—58. Guaiac test—negative. Uranalysis: No abnormalities.

Barium Meal: 50% six-hour residue. A large filling defect was found in the pars media and antral portion of the stomach, which corresponded to a mass palpated in the epigastrium. On the lesser curvature, near the filling defect in the antrum, a persistent barium projection is seen, one centimeter in depth and diameter—characteristic of a penetrating ulcer.

She was observed on the Medical Ward for a week, where she was seen by the surgeons, and everyone agreed with the diagnosis of carcinoma of the antrum of the stomach, and she was, therefore, transferred to the Surgical Service.

Operative Report.—Doctors Whipple and Nelson (March 6, 1940): Preoperative diagnosis: Carcinoma of the antrum. Postoperative diagnosis: Carcinoma of the head of the pancreas.

Partial gastrectomy; complete duodenectomy; removal of head and part of body of pancreas; anterior gastro-enterostomy, end-to-side; and choledocho-enterostomy.

Operative Pathology: The findings in this patient proved to be quite unexpected. Because of the patient's symptoms, the presence of a movable mass and the positive roentgenologic diagnosis of a carcinoma of the antrum of the stomach, the patient was operated upon with the idea of partial gastrectomy. When the thin abdominal wall was opened the mass could be felt in what was thought to be the posterior wall of the stomach. Because it moved easily the lesser sac was not opened to inspect the posterior wall of the stomach. This was a mistake, for the mass, which proved to be a tumor of the head of the pancreas, was not discovered until after the stomach had been transected. However, the ultimate procedure was not materially endangered because the patient was not jaundiced, and it was felt that a one-stage procedure could be carried out in this case—and it was essential to do so, once having cut through the stomach. The tumor mass was found to be occupying the head of the pancreas. It was hard, but moved over the underlying structures, and no enlarged nodes were felt. When it was being dissected away

* Read at meeting of New York Surgical Society and Philadelphia Academy of Surgery at N. Y. Academy of Medicine, February 14, 1945.

from the portal vein and the superior mesenteric vessels, great care had to be taken because it was thought that in another two or three weeks it probably would have begun invading the vessels.

Procedure: A left rectus incision was made. When the tumor mass was felt freely movable on what was thought to be the posterior wall of the stomach, a resection was begun by ligating the vessels in the greater and lesser curvatures at the junction of the upper and middle thirds. The stomach was cut across between Payr clamps and the proximal one covered with a protecting pad, as was the distal one, and the stomach drawn to the right, when it was discovered that the tumor mass was not in the stomach but in the head of the pancreas. The common duct was found to be dilated, although the patient was not jaundiced, and the cystic duct had a somewhat abnormally long course, and it was doubtful as to whether or not the gallbladder could be used for anastomotic purposes.

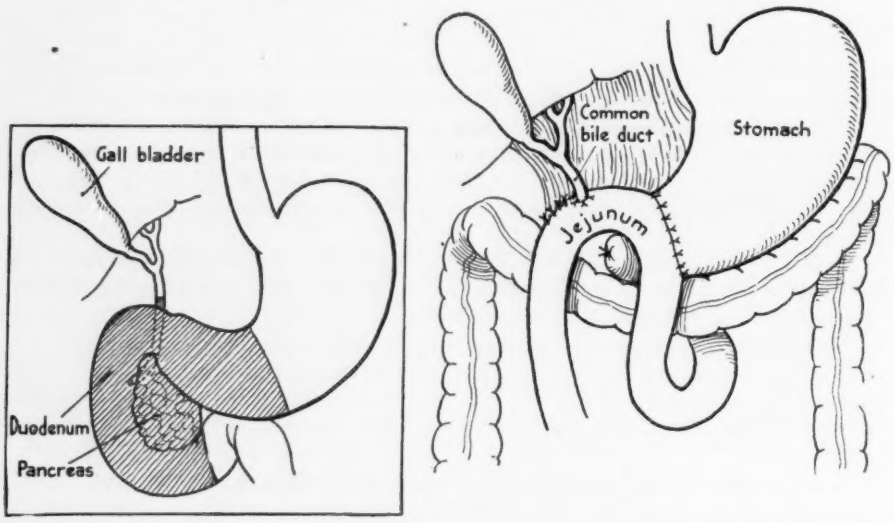

FIG. 1.—One-stage radical pancreaticoduodenectomy, with antecolic gastrojejunostomy and implantation of the common duct into the jejunum.

Inasmuch as the duct was dilated, it was decided to transplant it into the jejunum which would be used for the gastro-enterostomy. Furthermore, this made it easier to continue the dissection of the duodenum. The gastroduodenal artery was ligated, which controlled a good part of the arterial hemorrhage, and the dissection of the duodenum with the head of the pancreas was then begun.

The peritoneum to the outer side of the duodenum was incised, the duodenum mobilized, and the branches of the inferior pancreaticoduodenal artery ligated. The junction of the head and body was found to be narrow. It contained a dilated pancreatic duct which was ligated and the pancreas cut through. The junction of the duodenum and jejunum was then drawn to the right, behind the superior mesenteric vessels, and the duodenum cut between Payr clamps at the junction between the duodenum and jejunum. The distal cut end was then sutured with an over-and-over stitch of No. 00000 chromic and the stump was then buried with interrupted No. 1 silk mattress sutures. When the stump was released it passed behind the superior mesenteric vessels into the greater peritoneal cavity. With the freeing of the duodenum at this point the head of the pancreas was dissected away from the portal vein and splenic vein and from the superior mesenteric vessels. The patient did not lose much blood and the entire specimen of the distal half of the stomach and all of the duodenum and head of the pancreas and terminal

part of the common duct were removed. A loop of jejunum was then brought up in front of the colon and an antecolic gastrojejunostomy, end-to-side, was established between the cut end of the stomach and the antimesenteric border of the jejunum, beginning with a seroserous suture of C silk. The clamp was removed from the stomach and the contents of the stomach aspirated. An incision in the jejunum corresponding in length to the cut end of the stomach was made and the stomata united by No. ooooo chromic on two needles, beginning at the middle of the two adjacent parallel cut edges, locked at the angles and carried around to a point opposite the point of beginning, an over-and-over

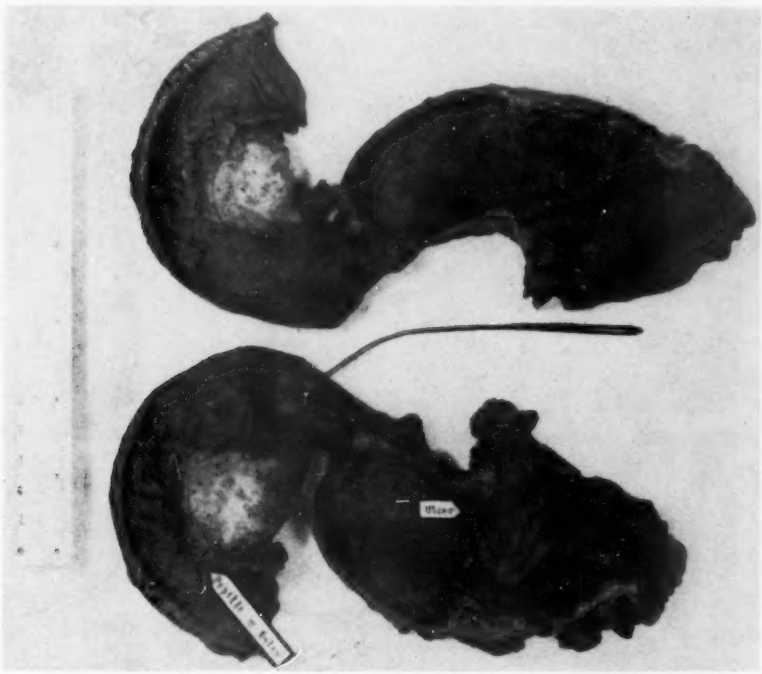

FIG. 2.—Gross-section of the tumor and duodenum, with probe through the common duct and papilla of Vater.

suture being used. The seroserous suture was then carried to the point of beginning. Finally, the cut end of the common duct was opened by removing the Kocher clamp, the excess bile aspirated and the anastomosis between it and the jejunum distal to the gastrojejunostomy was carried out by a seroserous suture of C silk. The opening in the common duct and an opening in the jejunum similar in diameter were united by an over-and-over suture of No. ooooo chromic and the seroserous suture carried around to the point of beginning. This completed the procedure. Hemostasis was found complete and the pad count reported correct. A Penrose tube was placed down to the bed of the pancreas.

Closure: Peritoneum and posterior rectus sheath with interrupted No. 1 silk mattress sutures; anterior rectus sheath with far- and near-interrupted sutures of C silk; skin with interrupted silk.

Condition—remarkably good. Medication—slow transfusion. Specimen—distal half of stomach, all of duodenum, head of pancreas, and terminal part of common duct. Drains —one Penrose tube. Case—clean-contaminated. Technic—silk.

The pathologist reported the tumor as being a carcinoma of the head of the pancreas, but of the islet cells rather than the acinar tissue. In addition a penetrating benign ulcer on the lesser curvature of the stomach was found (Fig. 2). Dr. Stout's report is as

FIG. 3

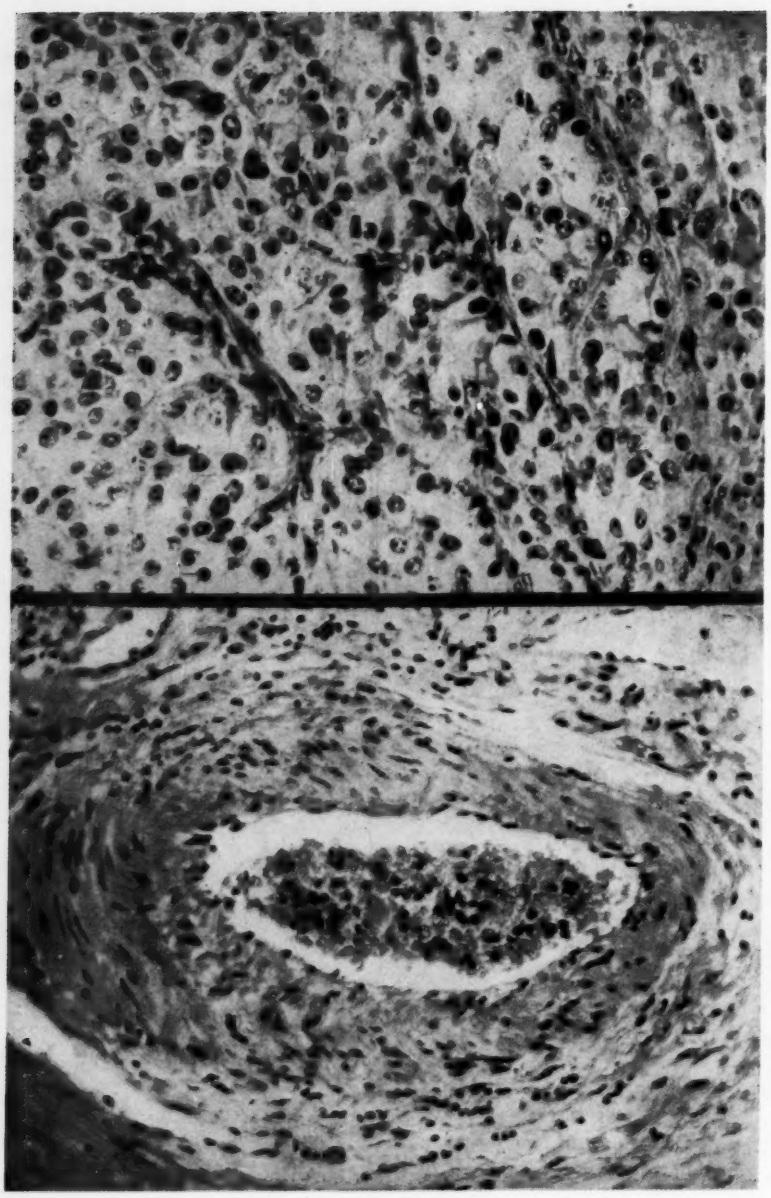

FIG. 4

FIG. 3.—Microscopic picture of the islet cell tumor of the pancreas.
FIG. 4.—Section of vessel showing islet cells in the lumen.

follows: "This appears to be a characteristic and well-differentiated tumor of islet cells. Most of the cells are filled with characteristic granules (Fig. 3), and it is surprising that the patient did not show clinical symptoms of hyperinsulinism before operation. The tumor has infiltrated the head of the pancreas, destroying most of it. It has surrounded and infiltrated the wall of the common duct as it passed through the head of the pancreas, and in this way narrowed the lumen. It has infiltrated many large and small veins (Fig. 4), so that the possibility of venous metastasis must be kept in mind. No lymph node metastases have been found in any of the lymph nodes examined. The remaining pancreatic tissue, except where it has been attacked by the tumor, is relatively normal in appearance and is well supplied with islets. The small ulcer high on the lesser curvature of the stomach has produced marked destruction of the muscular coat, although a few muscle bundles can still be noted in the scar tissue forming the bed of the ulcer." Dr. Virginia Kneeland Frantz reported as follows: "With Bensley's stain the granules all stain red. If the stain is reliable, which it has not been previously in our hands with human tissue, this would mean that the tumor is composed of *alpha* cells."

Fasting blood sugars after operation showed normal levels of 98 to 104 mg. per cent.

Subsequent Course.—The patient made an uneventful convalescence. She has been followed frequently in our Metabolism Clinic because of a fat indigestion. She shows from 30 to 50 per cent fat loss in her stools on repeated measured fat intake and output studies, but this fat loss in the stools is controlled somewhat by the use of 5 panteric and 9 holadin tablets o.d. Her weight is maintained at 90 to 94 pounds. She is still just as active and busy in her household duties and in work as a clergyman's wife in his parish as at any time before her operation. At no time has she shown any evidence of hyperinsulinism or of hypoglycemia either symptomatically or by fasting blood sugar determinations.

COMMENT: This is the first recorded one-stage removal of the head of the pancreas and duodenum, with occlusion of the pancreas. Trimble reported a similar procedure, carried out independently in a patient operated upon several weeks later. As a result of our experience in some 27 radical pancreaticoduodenectomies, 22 for malignant neoplasm and 5 for calcification of the pancreas, we now advocate the one-stage procedure for the following reasons:

1. The danger of hemorrhage and postoperative oozing is controlled by preoperative vitamin K therapy.

2. The danger of two anesthesias and two major procedures is avoided.

3. The difficulties of extensive and in some cases massive adhesions at the second and more difficult stage are avoided.

4. Continuous spinal anesthesia, together with plasma and whole blood transfusion, has made the one-stage procedure safer than the two-stage procedure. We have performed eight two-stage operations, with a mortality of 38 per cent, whereas, in 19 one-stage operations our postoperative mortality from all causes was 31 per cent. We have lost no patients with one-stage procedures for benign lesions.

5. In the one-stage procedure we have found two steps of great advantage:

(a) The implanting of the common duct into the jejunum, either end-to-end or end-to-side, depending on the choice of the loop or Roux-type of jejunojejunostomy. This avoids the dangers of a cholecysto-

enterostomy, and the serious complication of a biliary fistula as a result of the cutting through of the ligature on a ligated common duct.

(b) The implanting of the pancreatic duct into the jejunal loop below the choledochojejunostomy. This eliminates all the uncertainty and debate regarding an occluded pancreas and possible fatty liver degeneration.

There have been many modifications of the one- and two-stage procedures reported since our paper in 1935. Provided a cholecystogastrostomy and ligation of the common duct is not done, I believe it makes little difference what modification of the one-stage is used.

We regret that our subsequent reports on this subject are seldom referred to and that our original paper describing a two-stage procedure is always mentioned. Because of the newer advances in pre- and postoperative treatment, I condemn the two-stage procedure and advocate the one-stage procedure with choledochojejunostomy and implantation of the pancreatic duct into the jejunum as the procedure of choice.

SUPPURATIVE PANCREATITIS WITH ASSOCIATED LIVER ABSCESS*

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IN ACCORD with our own experience,[1] recent trends in the literature have emphasized the decreased mortality of acute pancreatitis when treated by the conservative nonoperative method, reserving operation for the complications of this disease, namely, pseudocyst and abscess. Within the past three years 19 cases of acute pancreatitis have been encountered in the Jefferson Medical College Hospital, 12 of the edematous type and seven of the hemorrhagic type. In the hemorrhagic group, pseudocyst formation occurred in two cases, and pancreatic abscess, also, in two cases. It is the purpose of this communication to present in detail one case from this series, unusual because of suppuration followed by hepatic abscess, to discuss its pathogenesis and evaluate the factors contributing to recovery.

Case Report.—A. T., female, age 55, was admitted to the Surgical "A" Ward Service of the Jefferson Medical College Hospital, September 30, 1944, with the chief complaint of epigastric and right upper abdominal pain.

The patient had been well until three days prior to admission, at which time she first experienced moderately severe epigastric and right upper abdominal pain. The pain was constant, did not radiate, and was accompanied by nausea and frequent episodes of vomiting of greenish-yellow material. She also had diarrhea, with passage of four loose stools daily for two days. From the onset of the attack she remained confined to bed and had fever.

The past medical history revealed that the patient previously had always enjoyed excellent health. She had been free of indigestion and was able to tolerate all types of food.

Physical Examination.—The patient was a moderately obese middle-aged Italian woman who was apprehensive, slightly irrational, and appeared acutely ill. Temperature 103° F.; pulse 130; respirations 26; and blood pressure 140/90. She was slightly jaundiced and markedly dehydrated. The heart and lungs were essentially normal. On inspection, the abdomen was slightly distended and abdominal respiratory movement was restricted. In the right upper quadrant there were exquisite tenderness, marked rigidity and rebound tenderness. No mass was noted at this time. Rectal examination, as well as the remainder of the physical examination, were essentially normal.

Laboratory Data.—Examination of the blood showed hemoglobin 78 per cent; red cells 4,000,000; white cells 13,600, with polymorphonuclear cells 57 per cent (8 per cent young forms), lymphocytes 39 per cent, monocytes 3 per cent, and basophils 1 per cent. Uranalysis revealed slight albuminuria, but was otherwise negative. Wassermann and Kahn serologic reactions were negative. The blood urea nitrogen was 9.0 mg., sugar 114 mg., and serum proteins 6.5 Gm. Van den Bergh test showed a positive direct reaction, with serum bilirubin of 2.1 mg. Bromsulfalein liver function study showed 20 per cent dye retention. The prothrombin time was 68 per cent of average normal.

* Presented before the Philadelphia Academy of Surgery, January 8, 1945.

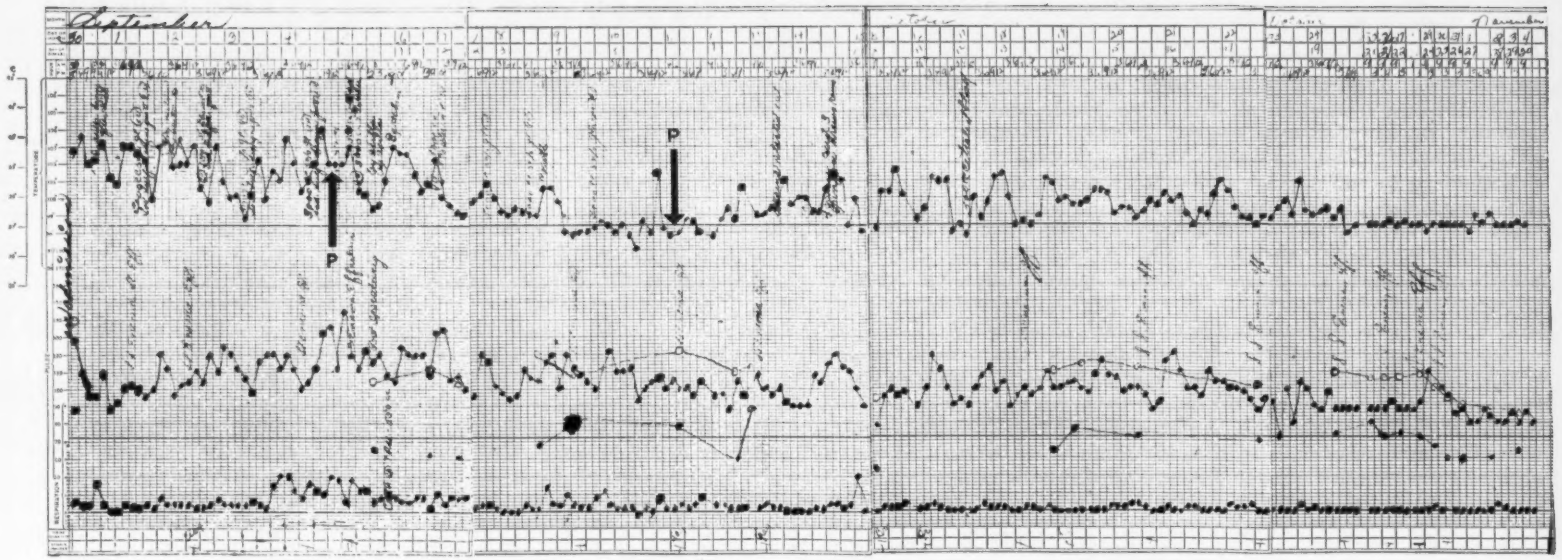

CHART 1.—Vital signs during first hospital admission. Large arrows (P) indicate start and termination of administration of penicillin.

The serum amylase, determined six days following the onset of symptoms, was normal. Blood culture revealed no growth in 48 hours. A plain roentgenogram of the abdomen was negative.

Preoperative Course.—It was thought that the patient had acute calculous cholecystitis. Accordingly, a conservative plan of treatment was instituted, consisting of Wangensteen suction; 5 per cent glucose in normal saline solution, with vitamin B_1 100 mg., vitamin C 100 mg., and vitamin K 4 mg. intravenously daily; also sodium sulfadiazine 5 Gm. intravenously daily. In spite of this therapy the patient failed to improve, and during the ensuing three days a mass became palpable in the right upper quadrant extending four fingers' breadth below the right costal margin. The temperature fluctuated daily between 100° F. and 103° F., and the pulse ranged between 100 and 120. On the fourth day of admission the patient developed grunting, shallow respirations at a rate of between 30 to 40 a minute, but there was no evidence of pneumonitis on physical examination. The leukocyte count rose to 18,000 by the third day of admission, 20,000 by the fourth, and 26,000 by the fifth day. At this time the administration of sodium sulfadiazine was discontinued and penicillin administered intramuscularly at two-hour intervals, with a total dosage of 100,000 Oxford units the first 24 hours and 50,000 units daily thereafter (Chart 1). On the sixth day the patient was operated upon, with a preoperative diagnosis of empyema of the gallbladder, and the contemplated procedure was cholecystostomy.

Operation.—Doctor Shallow, October 5, 1944: Under pontocaine spinal anesthesia, a right upper rectus muscle-splitting incision was made, and a slight excess of odorless turbid fluid was encountered in the peritoneal cavity. The gallbladder and biliary tract were free of any inflammatory process, easily compressible, and no stones were palpable. The anterior surface and lesser curvature of the stomach, as well as the duodenum, were next examined and showed no evidence of perforation. The gastrohepatic omentum was markedly congested, edematous, spotted with patchy areas of fat necrosis, and overlay a boggy mass protruding into the lesser peritoneal cavity. The gastrocolic omentum was likewise edematous and involved by scattered patches of fat necrosis. After walling-off the coils of bowel with saline gauze packs the gastrohepatic omentum was incised, and the lesser peritoneal cavity exposed. The posterior wall of the stomach and duodenum showed no evidence of perforation. Within the body of the pancreas was a fluctuant mass, which, following incision, was found to contain about eight ounces of extremely foul-smelling material of thin consistency and dish water color, in which small pieces of necrotic pancreatic tissue were suspended. Subsequent smear of this material revealed necrotic cellular débris, many gram-positive cocci, and the culture was positive for *Streptococcus hemolyticus.* Most of the body of the pancreas was destroyed by the abscess.

The quadrate lobe of the liver, on the inferior surface between the falciform ligament and the gallbladder, presented a slight bulge, suggestive of an underlying abscess. An aspirating needle was introduced and 5 cc. of pus was readily obtained. The liver was then incised over this area and a finger introduced. Two abscess cavities, in direct communication, were palpated. Four ounces of foul-smelling, thick, creamy-yellow material were aspirated, which on subsequent smear showed necrotic cellular débris, a few gram-positive cocci, and on culture were positive for *Streptococcus hemolyticus.* This hepatic abscess was entirely independent, showing no continuity or contiguity with the one in the pancreas.

Two iodoform packs and a Penrose drain were inserted into the abscess cavity of each organ and an additional Penrose drain was placed in the kidney pouch adjacent to the foramen of Winslow. These were brought out at the upper pole of the wound, which was then closed in layers. The patient received 500 cc. of citrated blood during the operation, which lasted 30 minutes, and she left in fair condition.

Postoperative Course.—The immediate postoperative response and convalescence

were essentially uneventful. She received 5 per cent glucose in saline, containing vitamins B, C, and K intravenously daily for four days; Wangensteen suction for four days; sodium sulfadiazine 5 Gm. intravenously daily for two days; penicillin 50,000 Oxford units daily in divided doses every two hours intramuscularly for six days (Chart 1); and 500 cc. of citrated blood on the seventh and twelfth days postoperatively.

Postoperative Laboratory Data.—Blood count (first day) showed hemoglobin 71 per cent; red cells 3,400,000; white cells 19,000 and 5,000 (fifteenth day). Repeated uranalyses were normal. The serum amylase was normal (first day); urea nitrogen 21.4 mg. (first day) and 18.8 mg. (fourth day); serum calcium 9.2 mg. (fourth day); positive direct van den Bergh reaction, with serum bilirubin 1.7 mg. (sixth day) and 0.5 mg. (21st day); bromsulfalein liver function study showed 5 per cent dye retention (sixth day), and no dye retention (21st day); and blood sugar 99 mg. (15th day).

The patient drained purulent material profusely through the wound during the first week, requiring change of dressings several times daily. During this time the jaundice began to subside, the temperature and pulse rate decreased, and the patient's mental state cleared. The drains were started out on the seventh day and completely removed on the tenth. The wound became mildly infected but responded to 0.8 per cent sulfanilamide irrigations and compresses. By the 20th day the jaundice had entirely subsided, the temperature and pulse had become normal and remained so until the patient was discharged, November 4, 1944, the 30th day postoperatively (Chart 1). At this time there was still slight drainage from the wound.

Second Hospital Admission.—The patient was readmitted 20 days later, November 24, 1944. Slight drainage from the wound had persisted, and three days before admission she developed fever.

Physical Examination.—Temperature 100.4° F.; pulse 110, and respirations 20. There was no jaundice, and her general appearance was the same as on discharge from the hospital. An area of tenderness and fluctuation was present in the upper half of the wound.

Laboratory Data.—Blood count revealed hemoglobin 65 per cent; red blood cells 3,900,000; and white cells 15,000. Three routine uranalyses were normal. The serum bilirubin was 0.6 mg.; bromsulfalein liver function test showed no dye retention; prothrombin time was 52 per cent of normal; and the serum proteins were 5.1 Gm. A plain roentgenogram of the abdomen was essentially negative.

Subsequent Treatment and Progress.—The tip of an hemostat was introduced into the upper pole of the wound, and about an ounce of greenish pus, positive on culture for *Streptococcus hemolyticus* and *Staphylococcus aureus*, obtained. The wound was irrigated twice daily, and compressed with 0.8 per cent sulfanilamide solution, and sulfadiazine was given orally so as to maintain a blood level around 5 mg. Vitamin B and K and bile salts were administered orally. Ferrous sulfate was given orally, and 500 cc. of citrated blood intravenously, following which the hemoglobin rose to 71 per cent. The patient was discharged, December 9, 1944, 15 days after admission, at which time drainage from the wound was almost negligible.

The patient was last seen, January 5, 1945, three months postoperatively. Her appetite was good, she had gained ten pounds in weight, was free of fever, and drainage from the wound had ceased.

COMMENT.—Suppurative pancreatitis usually occurs as a complication of hemorrhagic pancreatitis, resulting from bacterial invasion of the necrotic tissue. Less frequently it may occur as a result of ascending infection through the pancreatic duct. Pancreatic abscess has been produced in animals by injection of colon bacilli into the pancreatic duct. Ascending infection may occur when the biliary tract is the seat of inflammation, as in cholelithiasis

with cholangitis, with reflux of infected bile into the pancreatic duct in the presence of obstruction at the ampulla of Vater (cases of Mayo Robson[2]). Bevan[3] and Batchelor[4] have each reported a case associated with cholelithiasis. According to Opie,[5] pancreatic calculi are associated with pancreatic suppuration with relative frequency, and carcinoma compressing the pancreatic duct or carcinoma of the ampulla of Vater (case of Pearce[6]) may, likewise, be

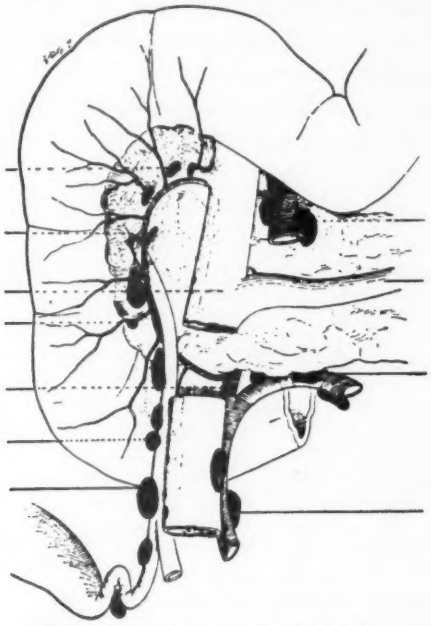

FIG. 1.—Posterior surface of duodenum and pancreas, showing relation of lymph nodes along the hepatic artery, cystic and common bile duct chains to those corresponding to the vascular arch behind the pancreas (Poirier, Cuneo, and Delamere).

associated with abscess of this gland. Pancreatic abscess may arise by extension from an adjacent organ by contiguity or through the lymphatics. Thus, abscess in the tail of the pancreas secondary to a perforated gastric malignant tumor has been reported by Ochsner.[7] Finally, hematogenous spread of infection to the pancreas may occur in rare instances.

Pancreatic abscess is usually associated with peritonitis of the lesser peritoneal cavity, and perforation into the general peritoneal cavity may occur. According to Opie[5] rupture into the stomach or intestine has followed, and vomiting or discharge from the bowel of purulent or hemorrhagic material has been reported. Associated thrombophlebitis of the splenic and portal vein may result in metastatic liver abscess. Destruction of a major portion of the gland may lead to the development of diabetes mellitus, as in the case of Beller and Nach.[8]

We believe that the sequence of events in the present case consisted of an attack of acute hemorrhagic pancreatitis followed by bacterial invasion, involvement of the pancreatic veins, and perhaps the splenic vein, by the

infection, and seeding of bacteria or septic emboli into the liver through the portal vein. The spread of infection from pancreas to liver by the lymphatics is also a possibility (Fig. 1). The finding of a normal preoperative serum amylase value on the sixth day following onset of the attack is in keeping with the well-substantiated fact, both in the literature and our own cases,[1] that the level usually falls to normal within 12 to 72 hours, and only in the minority of cases is elevated beyond this time (Chart 2).

The absence of biliary tract disease, both in the past history and operative findings, is of interest, since about 70 per cent of cases of acute pancreatitis

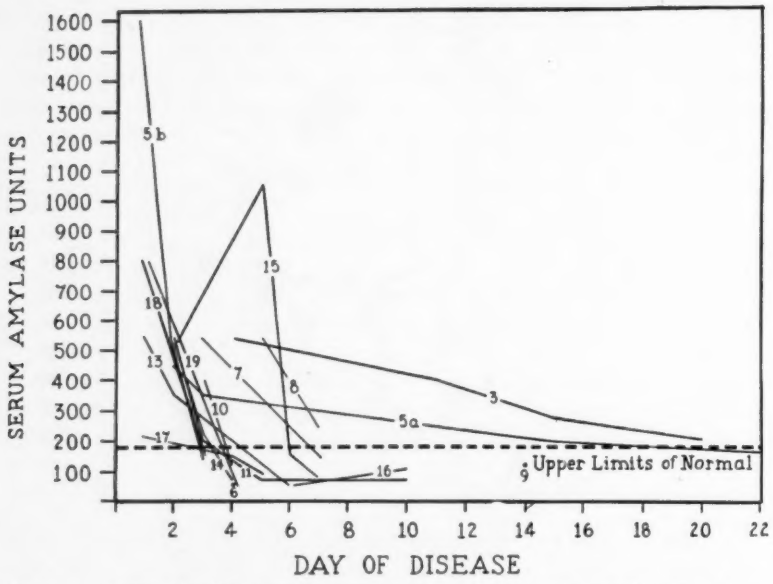

CHART 2.—Curves showing elevated serum amylase during acute attack, with fall as attack subsides. (Numbers on curves correspond to cases in authors' series.)

are associated with lesions in this system. The jaundice in this case was mainly due to hepatitis and possibly, to a lesser degree, to compression of the common bile duct in its transit through the gland by edema. Posterior perforation of a peptic ulcer into the pancreas was definitely ruled out at operation. The possibility of an hematogenous origin of the pancreatic abscess seems unlikely in view of the lack of clinical evidence of a primary focus elsewhere, and the negative blood culture.

According to the recent work of Edmondson and Berne,[9] serum calcium findings below 9 mg. per 100 cc. of blood usually occur in cases of pancreatic necrosis some time between the second and 15th day of the disease, and values below 7 mg. indicate a fatal prognosis. In keeping with this work, the value in the present case of 9.2 mg. on the 14th day following onset of the attack seemed to prognosticate a favorable outcome.

In this case the loss of pancreatic tissue did not result in diabetes mellitus. According to the work of Allen,[10] destruction of seven-eighths, or more, of the gland is necessary for a diabetic state to ensue.

The importance of scrupulous pre- and postoperative care in this serious condition is self-evident. Supportive measures, such as fluids intravenously, plasma, blood, and vitamins; Wangensteen suction to combat ileus; and chemotherapy with sulfonamides and penicillin are vital adjuncts in treatment. Because the infection was associated with gram-positive cocci, we believe that the use of penicillin for one week was an important factor in the patient's recovery.

CONCLUSIONS

1. Although the conservative nonoperative management of acute pancreatitis has been stressed in the recent literature, this case illustrates a clear-cut indication for surgical intervention, namely, abscess formation.

2. The finding of an associated liver abscess at operation is unusual.

3. Meticulous pre- and postoperative care, including the use of penicillin, are vital adjuncts to carefully timed and adequate surgical intervention.

4. Suppurative pancreatitis with associated liver abscess is a grave but not hopeless condition.

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FROZEN HUMAN SKIN GRAFTS

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PRESERVATION of free skin grafts up to one hour before replacement was begun in 1804 by Baronio.[1] Wentscher,[2] in 1903, was the first to use refrigerated free skin autografts. The period of preservation varied from 7 to 14 days. Filatov[3] treated some skin diseases by transplantation of cadaver skin preserved by refrigeration for several days. The transplant itself is lost and the good results are attributed to the production of autocatalysty. Refrigerated cornea, mucosa and vascular tissues were similarly employed. The same technic was employed with good results by Dellepiane-Rawson.[4]

The ability of cold-blooded animals and their organs to survive freezing for periods of time is well known. The successful transplantation of various types of tumors after freezing and thawing has been achieved by Klinke,[5] Breedis[6] and Cloudman.[7] Mider and Morton's[8] experiments suggested that skin might survive freezing and thawing in functional conditions.

Briggs and Jund[9] obtained 52 per cent of partial or complete takes using autoplastic grafts of frozen skin from young mice. Slow freezing to minus 78.5° C. was employed with slow thawing to 25° or 30° C. The period of storage varied from one to 24 hours.

Webster,[10] from his extensive experimental work, dating back to 1932, reported a total of 23 patients upon whom refrigerated skin grafts have been applied on 36 occasions. Most were split-thickness grafts. All but five were autogenous, and in most instances the period of preservation was less than 21 days. All autografts refrigerated over three weeks did not take. Homogenous grafts, likewise, disappeared. Webster also used one graft frozen to minus 72° C. and another dried from the frozen state. Both were kept for 17 days. The frozen graft was largely lost; portions of the skin dried from the frozen state fared better, with about 80 per cent take.

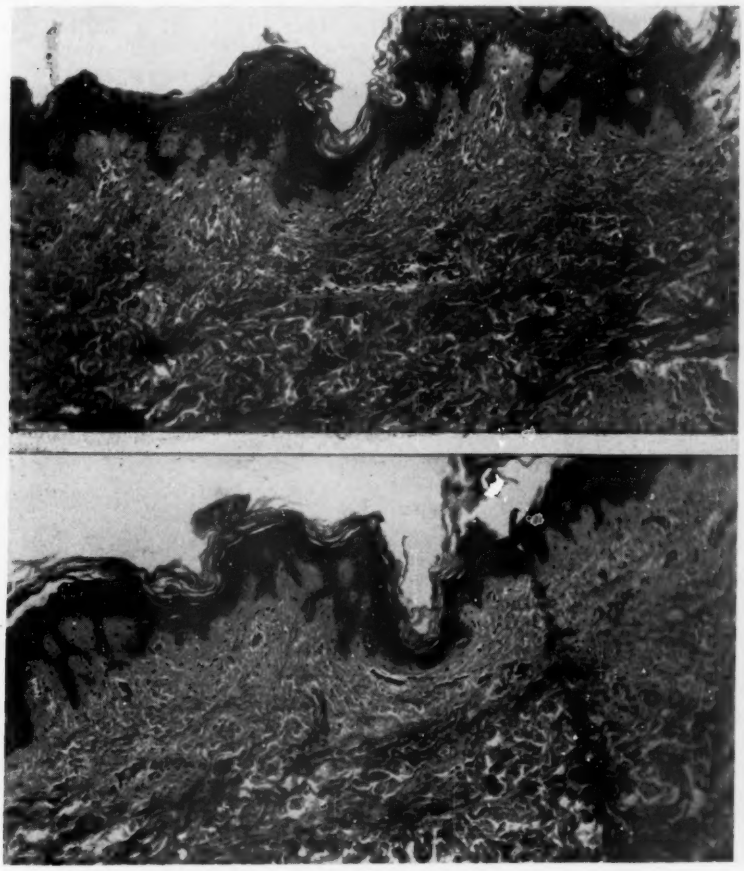
In the course of experimental work on the preservation of plasma in the frozen state,[11] it was found that under certain experimental conditions it is possible to retain all the physicochemical properties of complex colloids. These conditions are essentially rapid freezing, maintenance at a temperature below minus 15° C. and rapid thawing followed by warming to 37° C. Instantaneous freezing at very low temperatures is neither essential nor does it improve the final product.

In the process of drying of tissues from the frozen state prior to imbedding in a transparent plastic,[12] it was found that freezing and thawing of tissues from homothermic animals under conditions similar to those just mentioned was compatible with a very good preservation of all cellular structures (Fig. 1).

Our experimental work on preservation of human skin in the frozen state was begun in 1943 as a first step in the development of skin banks

for homologous grafts. In the work reported here only autogenous grafts were employed. The technic was as follows: The skin was prepared with green soap, water and ether. Following ether, split-thickness skin grafts were taken from the donor site with the Padgett dermatome.[13] These grafts

A



B

FIG. 1.—A—Normal fresh skin.
B—Skin frozen and preserved in the frozen state for three months.

measured 0.4 mm. in thickness. Segments measuring the full width and length of the Padgett dermatome were obtained and, in turn, these were cut into smaller sections depending upon the size of the recipient area. The controls varied from a section of skin measuring 7.5 cm. in width to 20 cm. in length to smaller segments depending upon the size and site of the recipient area. The segments of skin to be frozen were of a constant size measuring approximately 10 x 5 x 0.4 mm. These were immediately placed in citrated plasma. The plasma was fresh or preserved in the frozen state. Ten to 15 cc. of plasma have been found sufficient for about a dozen pieces of skin. The amount of plasma should be large enough to cover readily all skin pieces.

Pooled plasma as well as plasma from AB-group patients have been used. The best results have been obtained with plasma from AB-type patients. The bottle containing the plasma and skin grafts was closed with a rubber stopper, using aseptic technic and was immediately placed at minus 20° to minus 25° C. With 10 to 15 cc. of plasma in an ordinary vaccine bottle complete freezing took place in 15 to 30 minutes, depending on the initial temperature and the method of heat dissipation. The bottles were placed in a slanted position during freezing to minimize danger of breaking.

The skin frozen in plasma was maintained at minus 20° to minus 25° C. until ready for use. More rapid freezing or freezing and preservation at lower temperatures have not been found necessary.

At the scheduled time of transplanting, the frozen segments of skin in the plasma were allowed to thaw by placing the bottle in the water bath at 37° C. The skin segments were then transplanted to the recipient site without suturing and using only salt solution to prepare the donor area. A paraffin-mesh dressing over which moist saline sponges were placed followed with a pressure dressing of sponges and Ace bandages were the means utilized to provide uniform pressure. The dressings were not examined until one week had elapsed, and at that time the dressing was changed, and the percentage take was observed. The redressing subsequently was as often as indicated, usually at five-day intervals.

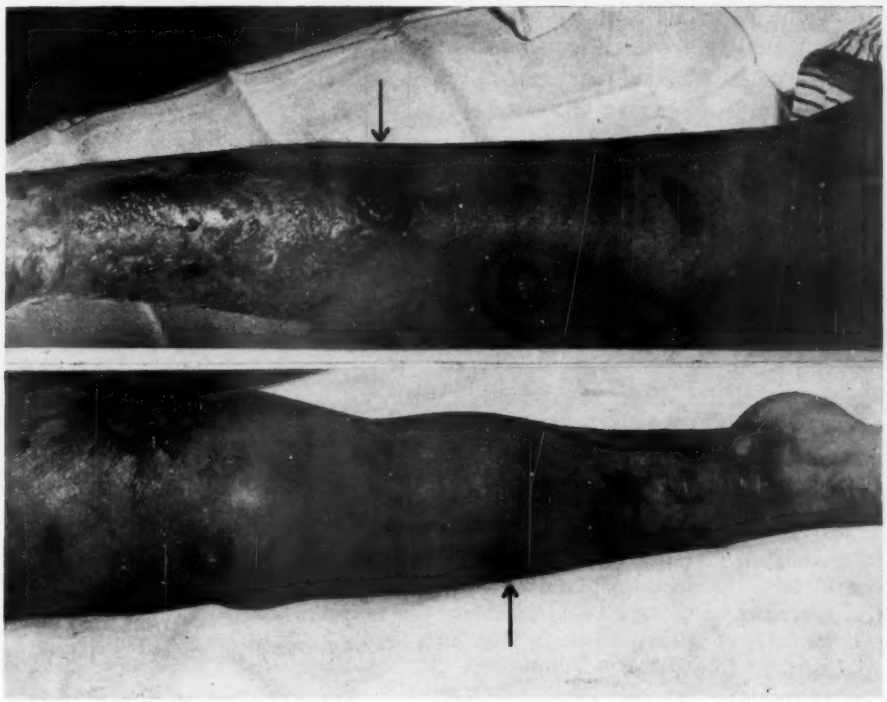
CASE REPORTS

Case 1.—A white woman, age 47, was admitted to the Bryn Mawr Hospital January 13, 1944, and discharged on June 8, 1944. The patient suffered from extensive 2nd and 3rd degree burns of arms, forearms, shoulders, thorax, abdomen and back. The 3rd degree burns were most extensive over the right shoulder, the left shoulder, the left forearm and arm and the left thorax, anteriorly and laterally. On February 26, 1944, split-thickness skin grafts were taken from the right thigh and were immediately transplanted as controls to the left arm and forearm. Ten pieces of skin, measuring 10 x 5 x 0.4 mm., were frozen, and next day were thawed and transplanted to the left arm and forearm. On March 5, 1944, all but one of the frozen grafts appeared to have taken. On March 12, 1944, the frozen grafts appeared healthy and showed definite increase in size. On March 7, 1944, split-thickness skin portions were taken from the left thigh and some were immediately transplanted as controls to the left arm and breast. Twelve sections of the size indicated above were frozen. On March 12, 1944, the frozen elements were transplanted to the left arm and breast. On March 19, 1944, there appeared to be six complete takes and two partial takes of the frozen grafts. On March 22, 1944, eight grafts of frozen skin out of 12 appeared viable and proliferating. On March 24, 1944, split-thickness skin grafts were taken from the left thigh. Some were immediately transplanted to the left forearm and 12 segments were frozen. On March 28, 1944, these skin elements were thawed and transplanted to the left forearm. Of the 12 frozen skin grafts, eight appeared to have completely taken, one partially. On April 7, 1944, the takes appeared to be proliferating more than the grafts that were transplanted without freezing.

SUMMARY.—The 25 control grafts of fresh skin showed 85.4 per cent takes; the 34 frozen skin grafts showed 78 per cent takes.

Case 2.—A white woman, age 78, was admitted to the Bryn Mawr Hospital on April 30, 1944, and discharged on June 17, 1944. The patient suffered from an extensive carcinoma simplex of the left breast with metastasis to axillary lymph nodes. The patient had had a previous right mastectomy in 1940. A radical mastectomy was performed on May 1, 1944. The skin loss was too extensive to perform closure without tension. Moderate sloughing occurred about wound margins, necessitating skin grafting. Split-thickness skin grafts were applied to the left chest, arm and abdomen on June 1, 1944. Three segments of skin, measuring 10 x 5 x 0.4 mm., were frozen. On August 1, after 61 days of preservation at minus 25° C., the three grafts were thawed and

A



B

FIG. 2.—Case No. 3: Frozen autogenous skin grafts. A—22 days; B—118 days after implantation.

transplanted to the ulcer on the left thorax. The wound was redressed on August 8, 1944, and all frozen elements appeared to have taken. There was a slight crusting of the frozen elements, with viability appearing certain. By August 15, the grafts appeared to have taken 100 per cent. On September 3, 1944, all refrigerated elements appeared to have taken completely.

SUMMARY.—The three control grafts of fresh skin showed 85 per cent takes; the three grafts of frozen skin showed 100 per cent takes.

Case 3.—A white male, age 5, was admitted to the Bryn Mawr Hospital on March 16, 1944, and discharged on June 4, 1944. He suffered from extensive 2nd and 3rd degree burns of the arms, forearms, thighs, leg and face. Split-thickness skin grafts were removed on May 4, 1944. Some were immediately transplanted to the left leg and thigh. Four pieces, measuring 10 x 5 x 0.4 mm., were frozen. On May 11, seven days later, the frozen skin grafts were thawed and implanted on the left leg. On May

17, the grafts appeared to have taken nicely. On June 24, 44 days after implantation, all grafts were doing well. Those which had been frozen appeared to be somewhat healthier than the control grafts at similar stages and were proliferating more than usual (Fig. 2). On September 11, four months later, all grafts had continued to grow nicely and had formed viable skin.

SUMMARY.—The six control grafts of fresh skin showed 96 per cent takes; the four grafts of frozen skin showed 100 per cent takes.

SUMMARY AND CONCLUSIONS

Forty-one autogenous split-thickness grafts preserved in the frozen state from one to 61 days at temperatures of minus 20° to minus 25° C. were transplanted to three patients. These grafts resulted in 80.5 per cent permanent takes. Thirty-four control grafts of fresh skin in the same patients resulted in 86.4 per cent takes.

The result of grafting does not appear to be affected by the time of storage of the grafts in the frozen state, at least within the experimental limits mentioned.

Aside from the possible development of skin banks for homografts, the preservation of split-thickness autogenous skin grafts in the frozen state allows the operator to obtain at one operation large numbers of grafts which may be employed for transplantation at any time later on.

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THE PYRUVIC ACID METHOD OF BURN SLOUGH REMOVAL

AN EXPERIMENTAL INVESTIGATION*

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THERE IS GENERAL AGREEMENT that the process of repair in any type of wound is favored by the early and complete removal of nonviable tissue. In the contused laceration, this débridement is accomplished by excision with

FIG. 1.—Condition of three experimental burns on Dog No. 7, on fourth day: Left upper, plain starch paste. Right upper, pyruvic acid paste. Small, irregular sloughs have been removed as indicated. The wounds are identical. Finger points to dry control, with no sign of sloughing.

the knife. Although such straightforward surgical treatment has been applied to burns occasionally, it has been assumed that a chemical method of slough removal would be preferable, owing to the difficulty in making an early and accurate determination of which areas will ultimately prove to be third-degree in depth.

Connor and Harvey[1] have described a procedure for the treatment of

* This work was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Development and the Henry Ford Hospital.

FIG. 2.—Dog No. 8 on fourth day: The sloughs are more clean-cut in this instance. No difference in effect of pyruvic acid paste and plain paste.

FIG. 3.—Dog No. 11 on the fourth day: Note the vascularized appearance of the granulating bases.

experimental third-degree burns which results in a surprisingly early separation of the slough. They reported a pleasing result in one clinical case. They had recalled that infection is often associated with rapid slough separation and had noted that the p_H of the exudate from the infected wound was frequently low, *i.e.*, of acid reaction. Therefore, the basis of their method was to bring the wound into an acid environment as far as possible. This

FIG. 4.—Effect of plain starch paste (left anterior burn) and tragacanth jelly (right anterior burn): Good sloughing of both occurred on fourth day.

was done by dressing the lesion with a generous amount of a paste containing enough pyruvic acid to bring the p_H down to 1.9. Small third-degree burns in dogs were produced by burning for 20 seconds with a gas flame. "The control burns were dressed within a few hours after burning with either dry gauze, vaselined gauze or a paste consisting of 8 per cent cornstarch in distilled water." The control wounds sloughed in 10 to 12 days. The burns treated with pyruvic acid paste sloughed in three days.

We have repeated this experiment with two changes in the procedure. A method of burning was used which probably produced a more uniform burn, and every treated lesion was checked with *two* controls on the same animal; one was left dry and the other was covered with the vehicle for the pyruvic acid, *i.e.*, plain starch paste.

Small or medium-sized dogs were used. A suitable area on the back was shaved, after which the animal was anesthetized with intravenous

nembutal. For making the burn, we used the flattened bottom of a pyrex test tube containing sulphuric acid which had been heated to 205° C. At the instant of contact, the temperature was usually about 200° C. and

TABLE I

Dog. No.	Seconds of Burning	Days Required for Sloughing		
		Plain Starch	Pyruvic Acid	Dry Control
1	15	3	3	17
2	45	4	4	9
3	15	4	4	11
4*	15	..	..	..
5	15	4	5	11
6	30	4	4	11
7	30	4	4	13
8	30	4	4	11
9	30	4	4	9
10	30	5	5	10
11	30	4	4	11
12	30	4	4	11

*None of the burns on this animal sloughed, due to short period of burning.

at the end of 30 seconds of burning was about 190° C. Two burns were placed anteriorly, one on each side. The third burn was placed posteriorly near the midline. In the first series of 12 animals, the right anterior burn was covered with the pyruvic acid paste, the left anterior was

TABLE II

TRAGACANTH JELLY *versus* PLAIN STARCH PASTE

All Burns were for 30 Seconds

Dog. No.	Days Required for Sloughing		
	Plain Starch	Tragacanth Jelly	Dry Control
B1	4	4	12
B2	3	3	11
B3	3	3	10
B4	3	3	10
B5	..	4	9
B6	..	4	7*

*Animal licked dry control wound.
(Only two burns made on animals B5 and B6)

covered with the plain paste, and the posterior burn was left dry and exposed. To prevent mixing of the two pastes, a "bridge" of dressing was placed between the wounds. Both layers of paste were covered with vaselined gauze and dry gauze, after which a substantial circular bandage of elastoplast was applied. During the first few days, additional paste of the appropriate kind was forced under the dressing by means of a small syringe of the asepto type. At these times, it was possible to get a partial view of the wound to see if sloughing was about to take place.

Figure 1 is typical of the appearance of the wounds on about the fourth day. The areas treated with either the pyruvic acid paste or the plain starch usually sloughed in the same period of time (3–5 days) while the dry

control needed about 12 days. Sometimes the sloughs were ragged, as in Figure 1, at other times they were clean-cut buttons (Fig. 2) and occasionally they were lost entirely (Fig. 3). The base of subcutaneous tissue which remained after the removal of the slough appeared to be healthy, as if it would take a skin graft.

FIG. 5.—Dog No. 21 on the second day: Upper wound dressed with wet cotton has sloughed. Dry control wound shows no sign of sloughing.

This experiment was carried out in 12 animals (36 burns), and the results may be seen in Table I. In no instance did the pyruvic acid paste prove to be superior to the plain starch paste.

We then repeated the experiment, substituting a presumably inert aqueous jelly base (tragacanth) for the pyruvic acid paste. The results in six animals are shown in Table II. The tragacanth jelly proved to be as efficacious in removing slough as either of the agents used in the preceding experiment (Fig. 4).

From the above experiments it appeared likely that sloughing would be promoted by keeping the burn *moist* by any method. Therefore, in the third set of experiments, only two burns were made on each animal, an anterior one which was dressed with absorbent cotton wet with distilled water, and a posterior dry control (Fig. 5). Table III gives the results obtained in nine dogs.

COMMENT

Early sloughing was produced by dressing the small third-degree burns with pyruvic acid in starch paste, plain 8 per cent starch paste, tragacanth

TABLE III

Dog No.	Days Required for Sloughing: Wet Cotton	Dry Control
13	4	9
14	6	22
15	4	15
16	5	16
17	Died (anesthesia)	
18	15*	16
19	3	14
20	3	11
21	2	9

*Vicious animal. Dressing received only initial wetting, and became dry.

jelly and cotton wet with distilled water. The only common factor appears to be the "wetness." It is suggested that the favorable effect on sloughing obtained with pyruvic acid paste is due more to maceration than to p_H. A dry gangrene has been converted to a wet one.

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BONE SARCOMA IN POLYOSTOTIC FIBROUS DYSPLASIA*

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WITHIN THE PAST DECADE the syndrome now commonly designated as fibrous dysplasia of bone has become increasingly recognized. In 1934, Goldhamer[1] recognized a disease which he characterized as osteodystrophia fibrosa unilateralis with pubertas praecox, and, in the same year, Borak and Doll[2] described what they called unilateral Recklinghausen's disease of bone with pubertas praecox. Almost simultaneously in this country appeared papers by Lichtenstein,[3] who employed the term "polyostotic fibrous dysplasia," and by Albright, Butler, Hampton and Smith[4] and Albright, Scoville and Sulkowitch,[5] who defined the process as a syndrome characterized by osteitis fibrosa disseminata, areas of pigmentation, and endocrine dysfunction, with precocious puberty in females. In 1942, Lichtenstein and Jaffe,[6] published an account of a large number of cases, with descriptions of their accessory features in addition to the skeletal lesions.

The present authors have no intention of again describing the syndrome. Their sole purpose is to place on record two instances of malignant bone tumor arising on the basis of fibrous dysplasia. Heretofore, so far as they know, this event has not been described, although cases doubtless exist.

In our first case, initially seen in 1929, the syndrome was, quite naturally, not recognized, although the characteristic pigmentation is described. Not until about ten years later did this case reach the proper clinicopathologic category.

CASE REPORTS

Case 1.—The patient, J. W., No. 40833, was a female, age 42, of Lithuanian ancestry. Her past history was uneventful. Five months prior to admission, she noted slight stiffness in her left shoulder. This increased during the following month and pain developed, especially on motion. Apparently, she first noted swelling in the shoulder region about two months after her first symptom. The swelling became progressively worse and two weeks prior to admission to the Memorial Hospital, the patient entered another hospital where a presumptive diagnosis of malignant bone tumor was made, whereupon she was referred to Memorial. During the two months prior to admission, the patient had lost about eight pounds in weight, suffered from occasional headaches and complained of a burning sensation over the left anterior chest wall.

The pertinent part of the initial examination concerns the local condition and the radiographic findings. The left scapula was the site of a large tumor mass, firm, rounded, nontender, possibly somewhat fluctuant. The entire shoulder region, anterior and posterior chest walls were the site of a brownish pigmentation which extended upward both anteriorly and posteriorly in the neck region. This pigmentation was essentially unilateral but reached slightly beyond the midline (Figs. 1 and 2).† There was marked limitation of motion of the left arm; abduction was essentially absent and anteropostero motions were but moderate.

* Submitted for publication February 17, 1945.

† 1941 photos; roentgen changes present in pigmented areas.

FIG. 2.—Pigmentation and enlargement of scapular area due to tumor. A late photograph.

FIG. 1.—Typical pigmentation essentially unilateral in character. Late photograph after treatment by irradiation. In the shoulder area the pigmentary changes are partly the result of irradiation.

Films of the left shoulder taken November 21, 1929, (Fig. 3) showed almost complete loss of outline of the left scapula which was replaced by a very large tumor mass, completely osteolytic, with only a few bony remnants remaining. The entire shaft of the left humerus showed altered architecture, with thinned cortex and multiloculated appearance of the medullary cavity.

Films of the chest of the same date (Fig. 4) showed marked deformity of most of the ribs, particularly on the left, with irregular expanded multiloculated areas. The lung fields appeared clear.

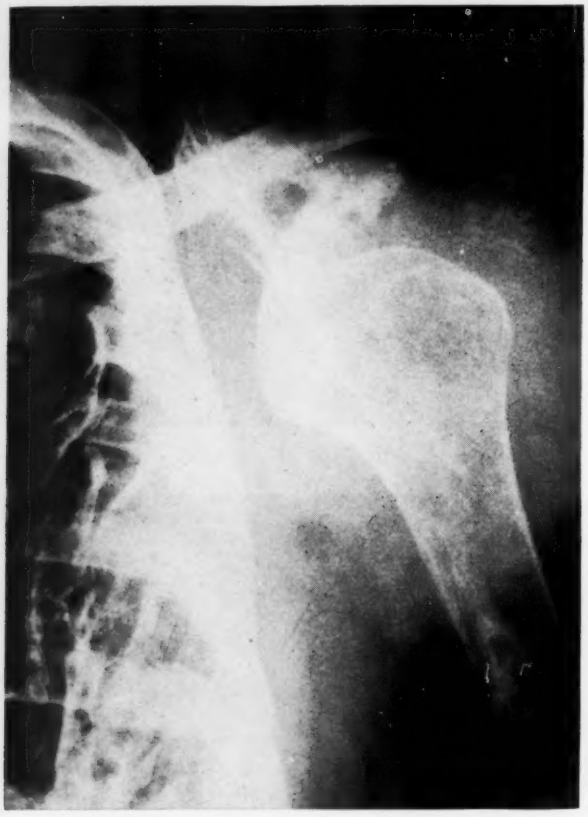

FIG. 3.—Osteolytic lesion of left scapula.* Humeral architecture with thinned cortex and multiloculated medullary cavity.

Films of the spine, pelvis and femora (Fig. 5) taken in December, 1929, showed no changes in the spine but the left ilium and the right pubis showed slight expansion and areas of decreased density similar to those seen elsewhere. Both femora showed widespread changes with decrease in density of the medullary cavities which latter were irregularly expanded.

Lateral films of the skull (Fig. 6) showed a pagetoid appearance of the entire skull and facial bones, with thickening of the tables and irregular areas of decreased density.

The scanty laboratory studies during this patient's first admission revealed nothing of significance unless a basal metabolic rate of plus 20 is indicative of some hyperthyroidism, since the latter has been emphasized in this disease. An aspiration biopsy was performed and yielded rare large atypical spindle cells, diagnostic of some type of sarcoma. Hence, a tentative diagnosis of medullary spindle cell sarcoma of bone was made.

The tumor was not considered suitable for radical surgery, since at that time it was not realized that the process in other areas was probably not sarcomatous, and the patient received a rather small amount of treatment with a radium emanation pack. This totaled but 28,000 mg. hrs. at 6 cm., and was administered on five successive days, between November 19, 1929, and November 23, 1929, through anterior and posterior portals. At the same time the patient received three roentgen-ray treatments to the left shoulder region, two over the rib areas and two to the skull, and between November 27, 1929, and January 7, 1930, she received Coley's toxin both intramuscularly and intravenously, with, on the whole, rather little reaction. Despite the seeming total inadequacy of the radiation, the patient's condition considerably improved. The tumor diminished in size, pain became much less severe and eventually vanished except for what the patient described as "slight pain with weather changes."

FIG. 4.—Rib deformity with numerous expanded multiloculated areas.

Radiographic reëxamination of the left shoulder on December 24, 1929, showed a marked improvement in the appearance of the scapula, with marked decrease in size of the tumor and beginning calcification suggesting regeneration.

The patient was again able to conduct her housework in a normal fashion and persistently refused to return to the clinic for observation. In fact, despite numerous appeals, she remained away for 11 years.

She reëntered the Hospital on July 9, 1941, and so far as the local findings were concerned the situation in the left shoulder was somewhat improved over that observed in 1929. Radiographs were reported as follows:

"Reëxamination of the left shoulder on July 10, 1941, shows some residual soft-part tumor, but there has been marked regeneration of the scapula, with reformation of the glenoid and vertebral border. The humerus shows no significant change from previous status."

Films of the chest on July 10, 1941, showed no apparent new changes in the ribs but there was increased density over the left chest, probably due to radiation. There was a large rounded shadow in the periphery of the right upper lung field which had the appearance of metastasis. The right humerus appeared normal. The pelvis showed no significant change. The skull again showed extensive changes which were better demonstrated and seen to be largely on the left.

The pigmentation was unchanged except for the addition of a large area of roentgen pigmentation, with scaling and telangiectasia. The patient's general condition had considerably declined. On this admission the laboratory studies were considerably more extensive. Red blood cells ranged from 2.5 to 2.9 million, except for a transient peak following transfusion. Calcium varied from 10.0 to 13 mg.; phosphorus from 2.82 to 4.11 mg.; alkaline phosphatase from 17.8 to 28.0 mg.; acid phosphatase was 0.56

units. Serum protein level on two determinations showed 7.8 and 8.1 per cent. Prothrombin level was 51 per cent. Chlorides ranged from 582 to 591 mg. Chloride tolerance was abnormal and appeared suggestive of adrenal cortical insufficiency. Blood cholesterol studies showed total cholesterol 164.3 mg., free 55.7 mg.; esters 108.6 mg. Bence-Jones studies were negative on several occasions. Two basal metabolic rate determinations were reported as plus 25 and plus 20.

FIG. 5.—Expanding areas of decreased density in femur.

Shortly after admission, but after a second aspiration biopsy, the patient developed a septic temperature ranging up to 103° F., and since no cause could be otherwise elicited, it was assumed that the source was infected tumor tissue. On July 30, 1941, an open biopsy was made of the scapular tumor.

The tumor tissue was soft, friable, yellowish to grayish, in places very hemorrhagic. It was about the consistency of chicken fat clot. On section (Fig. 7), it proved to be a highly pleomorphic, nonbone-forming, spindle and giant cell sarcoma. Giant cells reached enormous proportions and numerous atypical mitoses could be found. It was quite obvious that the tumor cells were identical with those obtained in the first material aspirated in 1929, and in the subsequent aspiration. This should be sufficient to dispel any doubt as to the existence of a malignant process in 1929, even in the mind of sceptics of aspiration as a diagnostic method, but poses a difficult question as to why a large osteolytic malignant tumor had remained for so many years prior to dissemination. This naturally is a question which the authors are unable to answer.

Since it became desirable to prove, by something other than radiographs, that this lesion had arisen on a basis of polyostotic fibrous dysplasia, it was determined to biopsy a supposedly nonneoplastic area for confirmation of this diagnosis. Hence, on August 14, 1941, an 8.5-cm. portion of left 8th rib was removed. On section, this tissue showed no evidence of tumor, and fulfilled all criteria for a microscopic diagnosis of fibrous dysplasia.

FIG. 6.—Pagetoid areas in skull and facial bones. An anteroposterior view revealed these to be mainly unilateral.

The patient was discharged, August 28, 1941, clinically improved. Again, she failed appointments, but this time evidently because of progress of tumor. Repeated attempts to persuade her to return to the hospital failed and she died at home on December 2, 1941. During the terminal phase of the illness she complained of abdominal discomfort, diarrhea and, evidently, the tumor of the left scapula had ulcerated and begun to fungate. A letter from her family physician stated that she had developed "intestinal" metastasis. Naturally, the authors are unable to confirm this finding in the absence of autopsy but in view of the radiographic finding in the right chest, see no reason to doubt the presence of abdominal disease.

Obviously, this tumor ran a most unusual clinical course. It was diagnosed as malignant bone tumor in 1929 on pathologic evidence, which we believe entirely reliable. With treatment, which should not have sufficed to control it, the patient experienced prolonged relief of symptoms, with regression and apparent quiescence of the tumor, and remained in relatively good condition for over 11 years.

Case 2.—The second patient, G. deP., No. 55274, was a male Italian, age 34. His past history was uneventful except for a primary luetic lesion many years prior to admission for which limited treatment had been given. His present illness began nine months prior to admission, when he noted pain in the left lower thigh and leg. This became worse and, about three months prior to admission, swelling of the left hip was first noted. The swelling increased rapidly in size and was accompanied by severe pain.

On admission, there was a bulky tumor mass involving the left hip laterally and posteriorly, and measuring 24 x 20 cm. in greatest dimensions. There was marked tenderness laterally over the greater trochanter. The bulk of the tumor was situated

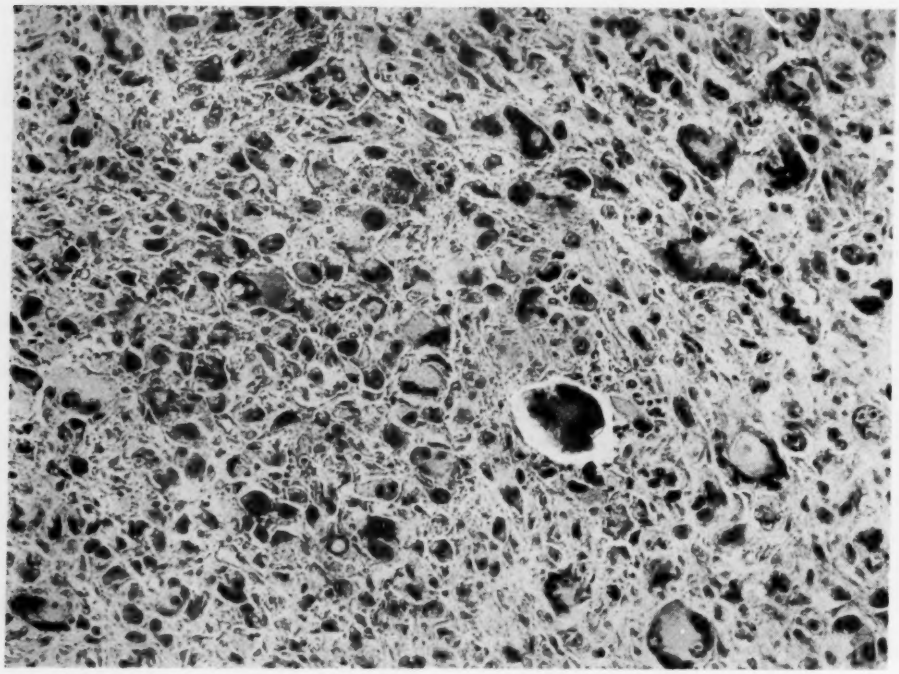

FIG. 7.—Pleomorphic large spindle and giant cell sarcoma.

posteriorly and was of firm, rubbery consistency. There was limitation of motion of the left hip in all directions mainly because of pain. There was no increase of local heat.

Films taken at the time of admission revealed a pattern considered classical for fibrous dysplasia. There were multiple somewhat expanding areas of bone rarefaction, together with zones of increased density involving the left pubic bone, left femur, particularly the neck region, and left tibia (Figs. 8 and 9).

On May 25, 1938, an aspiration biopsy was performed and a few cells were recovered which suggested malignant tumor. On May 31, 1938, the aspiration was repeated and a giant and spindle cell sarcoma, consistent with primary spindle cell sarcoma of bone, was diagnosed, both on smear and sectioned fragments of clot (Fig. 10). The resemblance to the previous case was striking.

Blood calcium ranged from 10 to 10.8 mg.; blood phosphorus from 2.6 to 3.8 mg. Phosphatase which ranged from 10 mg. on admission to 24.9 mg. on June 17, 1938, fell with treatment to 5.7 mg. on August 17, 1938. His basal metabolic rate was reported as plus 35, but for certain reasons this was considered inaccurate.

The patient was treated by roentgen ray, receiving a total of 18 treatments between

June 1, 1938, and June 21, 1938. Portals were anterior, lateral and posterior, approximately 15 x 18 cm. each. Daily doses were 300 r. for a total of 1800 r. per port. The patient experienced remarkable relief from pain, this relief being much more than would be expected for the ordinary malignant bone tumor. Flexion and extension returned to a considerable extent. On January 4, 1939, radiograms of the femur revealed considerable evidence of bone regeneration.

FIG. 8 FIG. 9

FIG. 8.—Multiple expanding areas of decreased density together with zones of increased density, left pubis and femur.
FIG. 9.—Similar areas of decreased and increased bone density, left tibia.

On March 8, 1939, the clinical improvement was regarded as so paradoxical that the question was raised as to the correctness of the diagnosis of osteogenic sarcoma. On November 8, 1939, the patient reported that he was essentially free from symptoms and no tumor was palpable, although diffuse thickening and firmness of muscles and subcutaneous tissues were noted. When referred for a check-up radiographic examination of the pelvis and left femur, however, he was found to have a pathologic fracture in the region of the intertrochanteric line with considerable shortening of the femoral shaft and coxa vara deformity. Approximately two months later further examinations showed no significant change. It appeared that a diagnosis of spindle cell sarcoma in an area of fibrous dysplasia was warranted, but to make more certain it was decided to obtain

tissue from the involved area of tibia and an open biopsy was performed on February 8, 1940. This tissue was reported as fibrous dysplasia.

The patient returned to the Follow-up Clinic until July 15, 1942. He had remained essentially symptom-free. In August, 1942, he entered another hospital complaining of epigastric pain and vomiting. His condition grew progressively worse and death occurred eight days after admission. No autopsy was obtained. Radiographs, however, are described as revealing an enlarged hilar shadow, with pulmonic infiltration, retraction

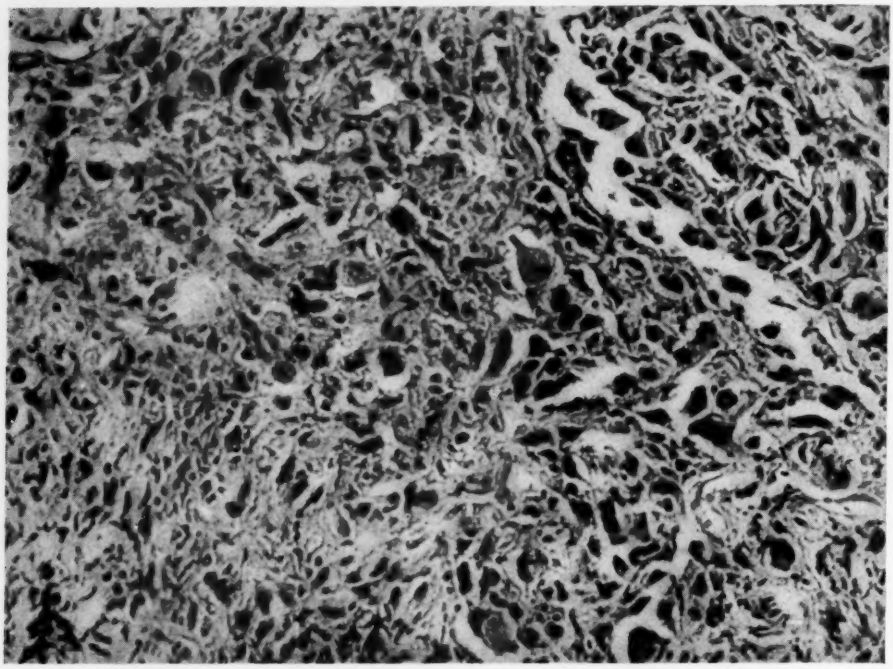

FIG. 10.—Pleomorphic spindle and giant cell sarcoma of left femur.

of heart and trachea to the right, thickened pleura, partial atelectasis of right lung. The radiologist's conclusion was tumor of the left hilar region with metastasis to bone. Naturally, the evidence points entirely toward the left femur as a primary source of tumor. Again, in the absence of autopsy, one cannot be absolutely certain that metastasis had occurred, but given the radiographic evidence pointing to metastasis, with full knowledge that a malignant bone tumor existed, a doubt seems scarcely justified.

SUMMARY

In conclusion, it may be stated that (1) polyostotic fibrous dysplasia may be added to the group of diseases of bone which may, in certain instances, develop malignant bone tumors. (2) In the two examples so far studied by us, the tumors have been essentially identical histologic pattern, namely, non-bone-forming pleomorphic spindle and giant cell sarcomas. (3) Both tumors appear to have produced metastases. (4) In both instances the response to radiotherapy has been unusual when compared to expected behavior of similar histologic types in different clinical settings. Whether this behavior will eventually prove part of a general clinical entity or not must await further cases.

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FINNEY-HOWELL FOUNDATION FELLOWSHIPS

At the meeting of the Board of the Finney-Howell Research Foundation, Inc., on March 2, 1945, fellowships were renewed for the third year for Dr. Nelicia Maier; for the second year for Drs. Muriel Virginia Bradley and Margaret Aston Kelsall; and a new fellowship was awarded Dr. Elizabeth Cavert Miller, to work in the University of Wisconsin.

Applications for fellowships for 1946 must be made to this office before December, 1945, to be eligible for consideration.

SPONTANEOUS RUPTURE OF AXILLARY ARTERY

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THE CASE to be reported is one of spontaneous rupture of the right axillary artery in a boy of fifteen. This followed a slight muscular effort, and ended in fatal hemorrhage. The autopsy disclosed unusual and unfamiliar alterations of the arterial wall, not only in the ruptured vessel but in several other intact medium-sized arteries. The extreme rarity of such an accident—only one similar case having come to our notice in a review of the literature—justifies a brief report.

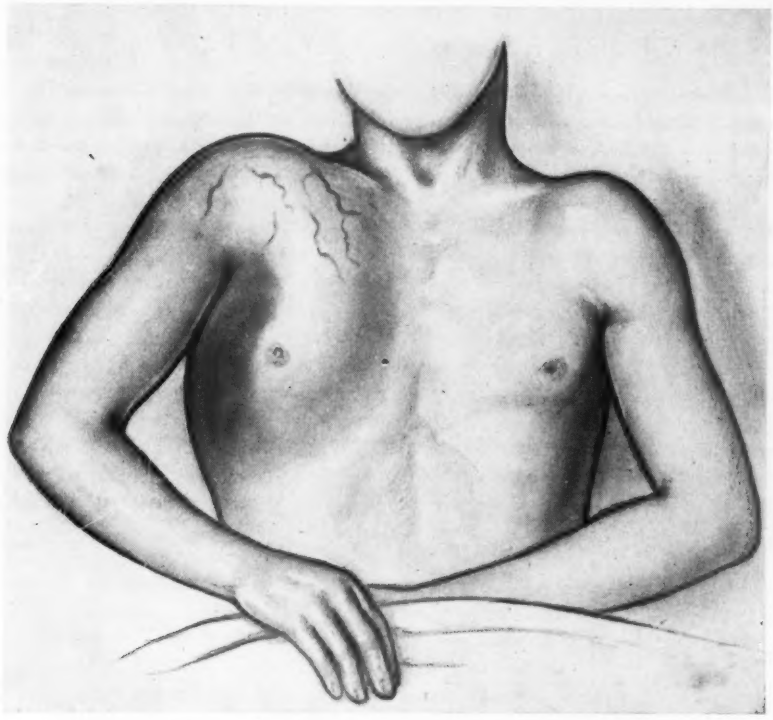
Case Report.—Unit No. 727939: J. D., a 15-year-old French school boy, was admitted to the Presbyterian Hospital complaining of pain, swelling, and discoloration of the skin and soft tissues about the right shoulder. Four days before admission, while playing football and throwing a "forward pass," he experienced a sudden sharp pain beneath the right clavicle with concurrent tingling sensation in the right arm, forearm, and hand. He stopped playing, and was without symptoms for 24 hours, except for soreness in the right pectoral region. Thirty-six hours after the original pain, while straining at stool, he felt a sudden swelling beneath the right clavicle and reported to the school physician who found the radial pulse normal, with no difference between the two sides; R.B.C. 4,220,000; W.B.C. 11,000; coagulation time 2.25 minutes, and bleeding time 2.75 minutes. The swelling progressed, occupying the entire upper pectoral region; and on the fourth day, the right radial pulse could no longer be palpated. The boy became pale and fainted several times during the day; his blood pressure fluctuated between 104/70 and 125/50. Color and temperature of the right arm were always good, but because of symptoms he was brought to the hospital.

The family history was irrelevant, but in the past history there are several pertinent facts. The boy was born in France and lived there until 1941. He was a six weeks premature baby weighing 3.5 pounds. As a child he was delicate and showed bruises from the slightest trauma. He had noticed, also, that any abrasion or cut bled longer than usual. Despite this hemorrhagic tendency, he had always been active in sports and athletics. No history of chronic or infectious diseases except diphtheria at the age of twelve for which he received diphtheria antitoxin. One year prior to admission, he had been hit in the right upper chest, just below the right clavicle, with a soft baseball. Soreness and slight swelling developed in this region following the trauma, but subsided in a few days without any other symptoms or untoward effects.

Physical Examination.—At time of admission: Temperature 99.8° F.; pulse (left radial) 124, (right radial) 0; respirations 22. The patient was a well-developed asthenic youth, pale, uncomfortable, and apprehensive. There was a swelling in the right pectoral region extending from the clavicle downward under the pectoral muscles and laterally into the axilla. Areas of ecchymosis were present over the axillary portion of the swelling, and the superficial veins over the right supraclavicular region were dilated and prominent. The right upper arm was slightly swollen (drawing). Both arms were equal in color and temperature, but no right radial pulse or blood pressure could be obtained. The remainder of the physical examination was irrelevant.

Laboratory Data.—Blood group O, Rh positive. Hb. 47 per cent; R.B.C. 2,530,000;

W.B.C. 24,500; 62 per cent neut.; 35 per cent lymph.; 3 per cent mono.; hematocrit 21.4 per cent; platelets adequate; prothrombin time 11.9 seconds; plasma proteins 5.54 Gm. per cent; venous clotting time 4.25 minutes. Roentgenogram of the chest: Lung fields clear. There is a line of increased density on the inner margin of the right apex. The soft tissues of the right lateral chest wall and axilla are markedly widened so that they measure about 10 cm. as compared to 3 cm. on the left side. This undoubtedly represents a large soft-tissue swelling, which probably overlies the chest and accounts for the increase in density in the right chest. Urine: Before operation 1+ albumin and an



Drawing showing appearance of the patient at time of admission.

occasional granular cast in the sediment, sp. gr. 1.027; the day following operation, the urine was normal, with sp. gr. of 1.017.

Course in Hospital.—First hospital day: After securing blood for grouping and cross-matching, the patient was taken to the operating room. The operation, however, was postponed as it was deemed expedient to improve his condition by transfusions of blood and plasma and infusions of saline because of his shock-like state and because of the extreme blood dilution caused by the hemorrhage. He was transfused with fresh citrated blood, 500 cc., from a professional donor. This was followed by 500 cc. of normal saline.

Second hospital day: The increased pain, axillary swelling, further decrease in both the hematocrit and plasma proteins indicated further internal hemorrhage demanding operative intervention. To prepare him for surgery, 500 cc. of fresh citrated blood from a professional donor and 1,000 cc. of recalcified plasma were transfused.

Operation.—Exploration and ligation of axillary artery and vein; partial expression of hematoma.

Pathology: "The pathology was one of the most striking pictures which we have seen of extravasation of an enormous amount of blood in the subpectoral region, outlined mesially and caudad by the limitations of the pectoral fascia and origin of the muscle. The skin of the chest wall was pushed forward for distance of 10+ cm. by an enormous hematoma beneath the pectoralis major primarily, extending from the midline to the lower ribs and laterally in the subscapular region and, in addition, pushing the shoulder cephalad to a marked degree. The axillary artery was torn through completely, presenting an irregular margin of all its coats. It seemed softer than normal. The axillary vein was intact."

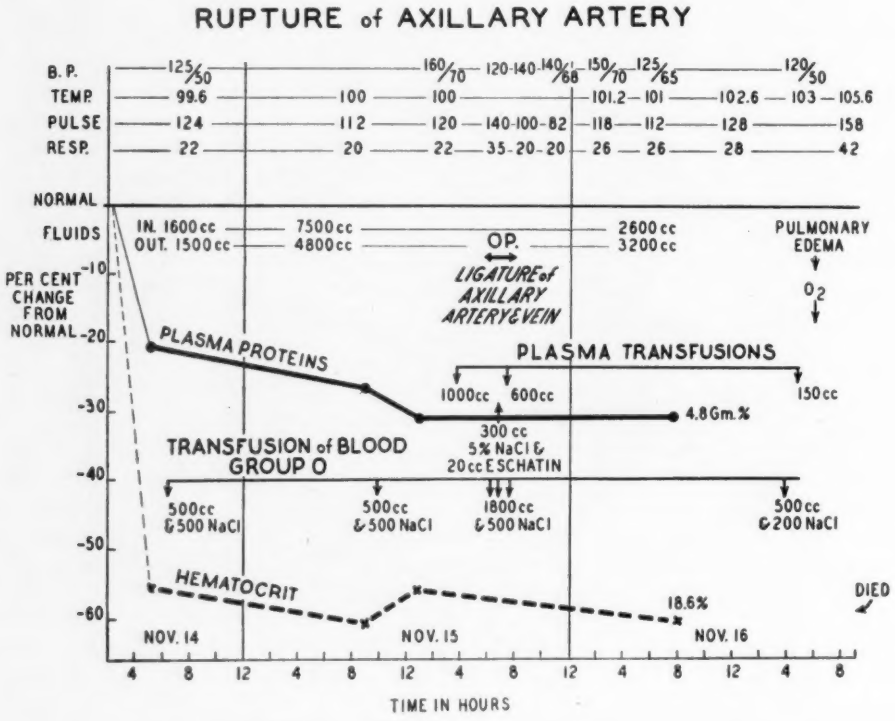


CHART I

Procedure: "After making an incision through the pectoralis major muscle, more or less parallel to the clavicle, which itself was about 4 cm. beneath the skin, the enormous hematoma or clot was found. This was evacuated in part and instantly a forceful gush of bright blood appeared from the region of the axillary artery. The bleeding was controlled by finger pressure against the clavicle above the site of laceration, after which, with suction and sponging, the lower end of the proximal axillary artery could be identified and clamped, controlling the hemorrhage." Artery ligated and wound closed about drain.

N.B.: "Before beginning the operation the systolic pressure was 100; at the termination the systolic pressure was 140, color improved. Two transfusions were started in the left arm and right ankle before the surgical procedure was begun. These were allowed to run slowly until the pectoralis major had been cut through and the clot evacuated, and during this period of critical bleeding both transfusions ran at full rate." In addition to 1,800 cc. of blood, he received 600 cc. of recalcified plasma, 300 cc. of 5 per cent NaCl, and 500 dog units of adrenal cortical extract. After operation:

500 cc. of saline with 5 Gm. of Na sulfadiazine. At 11:30 P.M. the patient's condition was remarkably improved; color much better. Blood pressure 140/68, pulse 82.

Third hospital day: Patient's temperature started to rise, and he complained of increasing pain in his arm and hand, requiring sedation. There was some oozing on the dressing, but this was not excessive. His condition, though critical, was not alarming. On account of the persistingly low hematocrit (18.6 per cent) and plasma proteins (4.8 Gm. per cent), a transfusion of citrated blood was given at 3:15 P.M. This was followed by plasma. Because of signs of pulmonary edema, the plasma was stopped after 150 cc. The temperature before the blood transfusion was 103° F. and, after 105.6° F. Patient died at 9:10 P.M., 26 hours after operation. The blood was rechecked and found compatible. Plasma from the same pool had been administered to two other patients without reaction.

Postmortem Examination.—Gross: The pertinent descriptive data are limited to the thorax and upper extremities: The mouth and nasal passages were filled with white frothy fluid and the mucous membranes were quite pale but slightly cyanotic. The neck was of normal contour except for soft swelling and bluish-purple discoloration of the subcutaneous tissues in the right supraclavicular fossa. This also extended over the entire right shoulder, the right anterior chest wall, right axilla, and the medial surface of the right upper arm. From a point in the midsternal line, 3 cm. below the sternal notch, extending laterally to the superior surface of the right shoulder was a recent surgical incision 28 cm. long. A cigarette drain protruded from the center of the incision, and thin sanguineous fluid exuded from the wick and about the drain. The upper extremities were of normal contour and color, except for edema of the left forearm, resulting from recent infusion which had extravasated. When the muscles were dissected from the chest wall, a large amount of dark red clotted blood, as well as fresh unclotted blood, was found in the right axilla, and between the right pectoralis major and minor. The muscles themselves were two to three times their usual thickness because of the extravasation of blood into their sheaths and between their fibers. There was no fracture of the clavicles, ribs, or sternum.

The right axillary artery in its first portion was intact, its lumen patent and 4 Mm. in diameter. No gross change was noted in its wall. The distal part of the second portion of the artery, posterior to the clavicle, had been ligated with a heavy braided silk suture and its lumen obliterated proximally over a distance of 7 Mm. by a firm blood clot. For a distance of 1 cm. above the ligature, there was a fusiform dilation of the vessel with its lumen measuring 6 Mm. across and its wall thinned-out to approximately 0.5 Mm. in contrast to the 1 to 1.2 Mm. thickness in the first portion of the artery. A thin, white line of tissue, about 0.5 to 1 Mm. thick, bridged the lumen, separating the clot into two portions. The third portion of the artery could not be found. The brachial artery was located in its sheath with vein and nerves, in the right axilla 3 cm. below the ligated stump of the axillary artery. It had not been ligated and its lumen was slightly dilated by a firm, friable, adherent blood clot for a distance of 2 cm. A white line of tissue, like that seen in the axillary artery, bisected the clot. Below this clot, the lumen was patent and the vessel wall normal in appearance.

The right axillary vein had been ligated and sectioned at a point level with that of the artery. Its lumen, distal to the ligature, contained a soft blood clot. Its wall was intact and apparently normal. The left axilla, with its veins, arteries, and nerves showed no evident deviation from the normal.

Thoracic cavity: The right pleural cavity contained approximately 500 cc. of thin, bloody fluid. No adhesions were present and the lung was expanded. The intact parietal pleura was smooth, but outside of it was dark purplish extravasated blood extending over the entire upper portion to the level of the sixth rib anteriorly and posteriorly. The left pleural cavity also contained 500 cc. of thin bloody fluid. The left lung was expanded and both layers of pleura were intact. The hemorrhage had extended into the soft loose

tissues of the mediastinum and up into the base of the neck. Sixty cubic centimeters of pericardial fluid was blood-tinged, but the lining of the sac was intact, white and glistening. The aorta was grossly normal except for hemorrhage in its adventitia in its upper half. The right lung weighed 640 Gm., the left 800 Gm. Edema was the only positive finding.

The remaining viscera were not unusual.

*Microscopic.**—Right axillary artery: The lumen of the vessel just above the ligature was occluded by a fresh thrombus, and a recent small dissecting aneurysm was found. It began at a point approximately 5 Mm. above the ligation in a shallow rent in the

FIG. 1.—Proximal Right Axillary Artery (trichrome stain): Fibrosis and dissection of arterial wall. (Low power)

intima and extended distally into the media throughout the dilated distal part of the artery (Fig. 1). The same change was seen in a section taken through the proximal portion of the brachial artery, into which the dissecting aneurysm had apparently extended. In several sections, just proximal to the ligature, the hemorrhage penetrated the adventitia and the surrounding fibro-areolar tissue.

The changes in the wall of both axillary arteries, the celiac axis, and the renal arteries were most unusual and worthy of detailed description.

Localized segments of the wall of the *right axillary artery* were thickened. In these locations the internal elastic lamella could not be identified and the intima and media appeared as one thick mass of pale musculo-connective tissue containing widely separated spindle cells embedded in a matrix of loose unstained fibrils. *Elastic tissue stain* revealed

*All sections of the arteries were stained with hematoxylin and eosin; Masson's trichrome; elastic tissue (Hart's modification); Levaditi; and Gram.

numerous delicate, fragmented, sometimes granular elastic fibers in these thickened areas, and only in a few portions of the vessel wall was the regular alignment of medial elastic lamellae encountered, and this usually in the thinner portions of the vessel wall (Plate IA). *Trichrome stain* proved the abundance of irregular, delicate collagen fibers between the elastic tissue as well as a paucity and focal absence of muscle cells. The deepest layers of media and adventitia were merged throughout two-thirds of the circumference of the vessel and by trichrome stain were found to be composed of dense, blue-staining, acellular fibrous tissue (Plate IB). Well preserved erythrocytes and fragments of fibrin were present in the surrounding loose fibro-areolar tissues. Levaditi and Gram stain revealed no micro-organisms. The dissecting aneurysm, previously described, began in one of these thickened regions of the right axillary artery.

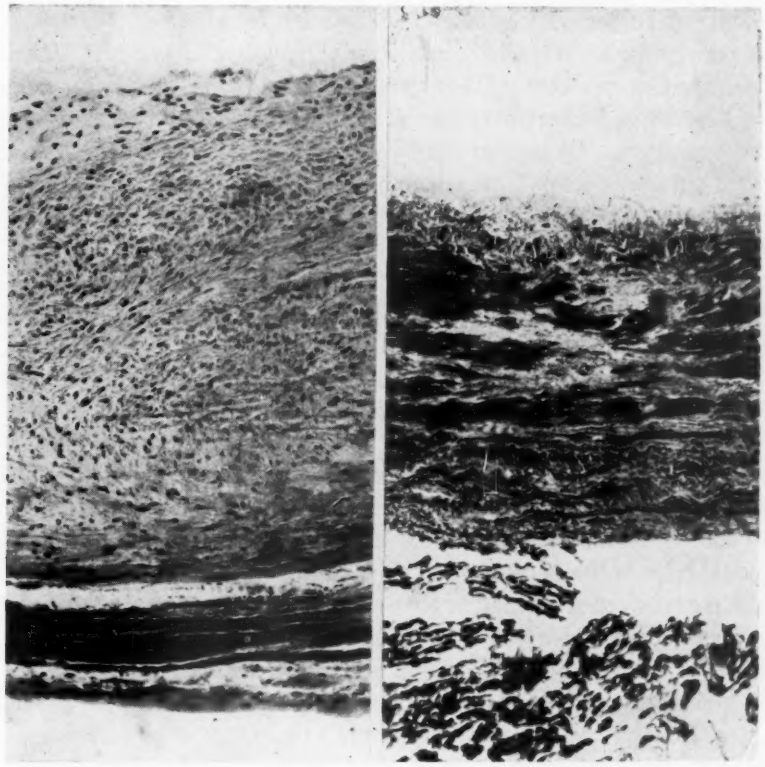


FIG. 2 FIG. 3

FIG. 2.—Left Axillary Artery (H. and E. stain): Disorderly arrangement of fibers. (×110)

FIG. 3.—Celiac Artery (trichrome stain): Musculature in many places is defective and somewhat irregular in arrangement. (×110)

In the *left axillary artery*, the irregular thickening of the wall, though present, was less pronounced. Intima and media could not be differentiated and the internal elastic lamella could not be identified (Fig. 2). At several points the deepest layer of media and adjacent adventitia were fibrosed but not appreciably thickened. In many portions of the media, the normal arrangement of the elements was destroyed, and instead there was found a disorderly mixture of muscle cells, collagen, and elastic fibers with no circumferential alignment (Plate IC). By *elastic tissue stain* the intimal elastic lamella was rarely recognizable; the intima, in consequence, was not sharply differentiated from the media. In the inner layer of media there was condensation of elastic fibers, two or three

deep. These were thin, quite delicate, and similar to those in the remainder and deeper portions of the media. The deepest layer of media and adventitia were fibrosed and their line of demarcation indistinguishable.

Other arteries: The changes in the celiac axis, pancreaticoduodenal, and renal arteries, though much less intense than in the axillary vessels, were of the same general character (Fig. 3). The musculature in many places was defective and somewhat irregular in its arrangement. Often the bundles of muscle fibers were quite widely separated by loose fibrillar collagen and by elastic fibrils, fragmented and delicate, or condensed and granular.

DISCUSSION.—The question of support and the nature of therapy needs comment in this boy, who had been critically ill for four days, with an increasing mass in his right axilla accompanied by a rapidly falling red blood count and signs of circulatory insufficiency, as reflected by his pallor and episodes of syncope. His admission hematocrit was 21.4 per cent and plasma proteins 5.54 Gm. per cent. He obviously needed blood, and, after determining his Rh factor, he was given fresh citrated blood on admission and just prior to operation. To combat the hypoproteinemia he received 1,000 cc. of recalcified plasma (plasma from which most of the fibrinogen has been removed by shaking with calcium chloride). This plasma assays between 70–90 mg. per cent of calcium, 5–6 Gm. per cent of proteins.

During the operation, 1,800 cc. of blood was transfused within a period of two hours. This was *citrated* blood. The total amount of citrate administered in 48 hours was 24 Gm. In retrospect, this may have been *too* much, as he developed pulmonary edema and showed blood-tinged fluid in the pleural and pericardial cavities. The dangers of too much citrate have recently been stressed.[1, 4] The decrease in ionized calcium in hypoproteinemia, graphically illustrated by Hastings and McLean,[7] is of peculiar interest in this boy whose proteins continued to decrease.

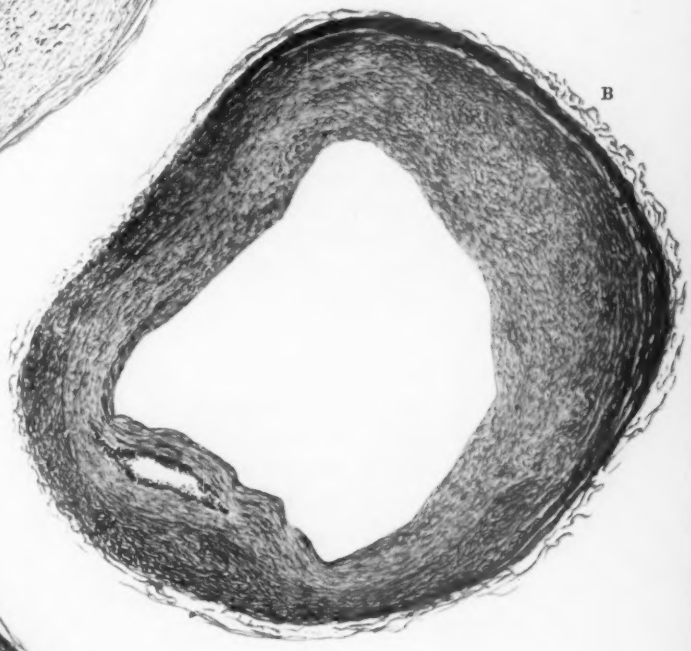
He should have been given *direct whole blood transfusions* on admission, and should have been operated upon then. On account of his low proteins, he should have received *serum* rather than plasma. Today, serum is being prepared at the Presbyterian Hospital Blood Bank for surgical cases with low proteins and for the treatment of infants with hypoproteinemia.

The main interest in this case concerns the pathogenesis of the arterial lesions. Three possibilities come to mind: (1) The arterial lesions represent a constitutional malformation; (2) they are the effect of some unknown dietary deficiency; and (3) they are the late result of some vascular toxin upon the media. A specific infectious etiology seems highly improbable in the absence of any inflammatory reaction, either local or systemic.

It is difficult to produce any arguments either for or against the idea that these vascular changes are congenital or constitutional. The history states that the boy had always been frail and had bruised easily; this might be taken as indicating vascular fragility. The literature on congenital hypoplasia of blood vessels refers chiefly to the aorta and the cerebral arteries. The somatic vessels seem to have been little investigated from this point of view. The changes described by Hansemann, Askanazy, Orliansky, and Wiesner[3] do not tally with those found in this case, nor is there any record of such

A

A.—Right Axillary Artery (elastic tissue stain): This reveals numerous delicate, fragmented, sometimes granular elastic fibers in these thickened areas, and only in a few portions of the vessel wall is the regular alignment of medial elastic lamellae encountered, and this usually in the thinner portions of the vessel wall.



B

B.—Proximal Right Axillary Artery (trichrome stain): An abundance of irregular, delicate collagen fibers between the elastic tissue as well as a paucity and focal absence of muscle cells. The deepest layers of media and adventitia are merged throughout two-thirds of the circumference of the vessel, and by trichrome stain are found to be composed of dense, blue-staining, acellular fibrous tissue.

C

C.—Left Axillary Artery (elastic tissue stain): The intimal elastic lamella is rarely recognizable. The intima in consequence is not sharply differentiated from the media. In the inner layer of the media there is a condensation of elastic fibers, two or three deep. These are thin, quite delicate, and similar to those in the remainder and deeper portions of the media. The deepest layer of the media and aventitia are fibrosed and their line of demarcation indistinguishable.

congenital hypoplasia leading to spontaneous rupture except in the miliary cerebral aneurysms. On the other hand, the local defects in the vascular smooth muscle, with derangement of the normal relation between muscle fibers, elastic fibers, and connective tissue, suggests an architectural anomaly rather than cicatrization from previous destruction.

Vitamin deficiency has also been considered. This child lived in a period of deprivation during the last four years of life in France, and presumably had suffered the dietary restrictions incident to the war. However, we have no information regarding specific vitamin deficiencies in his diet, nor have similar vascular lesions been recognized to result from deficiency of any of the known vitamins. Actual necrosis of muscle fibers, with calcification, as described by Opper[8] in vitamin A deficient rats, was not present in this case.

At the age of one year, the child was immunized against diphtheria. Eleven years later he had diphtheria. It is not definitely known whether he received antitoxin at this time. Subsequently, at the age of fourteen, he received, however, two injections of combined diphtheria and tetanus toxoid, two months apart. In view of this history, the question may be raised as to whether the vascular lesions may be attributed to the diphtheria toxin. It is well known that medial degeneration of the aorta, usually with calcification, may be readily produced in rabbits by diphtheria toxin.[2] However, in this case there is no necrosis or calcification, or destruction of elastic fibers. The lesions were confined to the larger peripheral vessels and were not present in the aorta. These points speak against their having been caused by diphtheria toxin.

We have found few references of similar cases, but one most similar is reported, in 1928, by Koch[5]: A 22-year-old athlete engaged in a variety of training exercises, after a test in swimming (breast-stroke), experienced pain in right shoulder. Shortly thereafter, he lifted a 50-Kg. weight on a machine; this was followed by a very acute pain in the right arm, thorax, and shoulder, with faintness, vomiting, dyspnea. After six days, he felt somewhat better and started for the moving picture theater, but collapsed on the street. He partially recovered, but died suddenly in bed eight days later, 15 days after attack. *Autopsy:* Old and recent hemorrhage into pleural cavity. Complete tear across right subclavian artery, 3 cm. distal from origin from innominate. The site of rupture was surrounded by aneurysm-like sac formed by adventitia. The right leaf of diaphragm showed a 15-cm. tear involving muscle and overlying pleura. Microscopic examination disclosed no changes in arterial walls to explain the spontaneous rupture, but details are not given. Heart and other vessels were described as normal. Another somewhat similar case is reported by Longland,[6] in which "all vessels were normal and the ruptured vessel showed one departure from normal in that some of the muscle nuclei in the neighborhood of the rupture were pyknotic."

In reviewing cases of spontaneous rupture of the inferior epigastric and internal mammary arteries, we found that practically all of these vessels

were the site of known and familiar changes, *i.e.*, periarteritis nodosa, Mönckeberg's sclerosis, arteriosclerosis, aneurysm resulting from arteriosclerotic changes, medial necrosis, or some type of arteritis. In the last case, there was usually a history of some relatively recent infectious disease.

SUMMARY

A case of spontaneous rupture of the right axillary artery following slight exertion, in a 15-year-old boy, is described.

Study of the large peripheral arteries showed an histologic malformation in the arrangement of the various components of the arterial wall. The pathogenesis of these lesions is briefly discussed, but no conclusion reached as to etiology. The descriptive term, "arterial myopathy," is suggested to designate these unusual changes which appear to have resulted either from primary developmental defect or secondary loss of medial musculature.

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AN UNUSUAL CASE OF MECKEL'S DIVERTICULUM

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AND

LT. COL. MEREDITH G. BEAVER, M.C., A.U.S.

MECKEL'S DIVERTICULA have been grouped, roughly, into four clinical types: (1) Catarrhal inflammation, with or without associated regional complications; (2) those producing intestinal obstruction; (3) gangrene of Meckel's diverticulum; and (4) peptic ulcers due to the presence of ectopic gastric tissue.[1] Although it is not uncommon to discover a persistent Meckel's diverticulum falling into one, or even perhaps two, of the above groups, it is rather rare and unusual, we feel, to encounter one which embraces three of these types.

The case we are reporting presented a galaxy of abnormal findings. Not only was the diverticulum abnormally long, but it had also undergone acute inflammatory changes; it had produced an almost complete small bowel obstruction; it had ectopic gastric mucosa, which had undergone peptic ulceration; and, to make the case complete, was associated with a pathologic diagnosis of early acute appendicitis. This combination of pathology, namely, acute Meckel's diverticulitis, intestinal obstruction, peptic ulceration, and acute appendicitis, is of sufficient rarity and interest to warrant being reported.

Case Report.—The patient, age 20, was admitted to Torney General Hospital, April 10, 1944, stating that he had been ill some 36 hours prior to admission. His illness consisted of lower abdominal cramps, without diarrhea. Five hours prior to admission these cramps, which had occurred at intervals of five to ten minutes and had been moderately severe, had been replaced by a persistent severe subumbilical and right lower quadrant pain. There had been no melena or dark stools. The patient had vomited only once. He had had no bowel movement for two days prior to admission, nor had he had any previous similar attacks. There were no symptoms referable to his cardiorespiratory, genito-urinary or eye, ear, nose and throat systems.

His family history was noncontributory. His previous personal history revealed that he had had the usual childhood diseases. History which was obtained subsequent to operation revealed that until the age of six he had had recurrent drainage and bulging of the umbilicus. This had been quite severe and had necessitated frequent visits to the doctor. The umbilicus was finally cauterized, and the drainage stopped at the age of six.

Physical Examination.—The patient was a well-developed and well-nourished male, who appeared to be semi-acutely ill. There was moderate cyanosis of the lips and skin. Temperature, 100° F.; pulse, 120; respirations, 18.

Essential physical findings were limited to the heart and abdomen. The heart was of normal size. There was an aortic systolic murmur which was transmitted to the vessels of the neck. The cardiologist felt that this murmur was functional in character. The electrocardiogram was reported as being normal. The abdomen was of normal contour. There was voluntary and involuntary guarding and tenderness, both subumbilically and in the right rectus muscle, just to the right and at the same level of the umbilicus. The tenderness in this area was rebound in character and

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pressure on other points of the abdomen referred the tenderness to the right lower quadrant. There were no masses or viscera palpable. Rectal examination revealed exquisite tenderness high in the right rectal vault.

Laboratory studies revealed a white blood count of 12,400, with 83 per cent neutrophils. Urine was negative. *Preoperative Diagnosis:* Acute appendicitis.

Operation.—Under nitrous oxide and ether anesthesia, a McBurney incision was

2
1
1 TERMINAL ILEUM AND MECKEL'S DIVERTICULUM ARISING FROM IT AND ATTACHED TO THE UMBILICUS.
2 DILATED AND COLLAPSED PORTIONS OF THE OBSTRUCTED SMALL INTESTINE.

FIG. 1

Photograph of the drawing through the courtesy of the U. S. Army Signal Corps

made. The appendix appeared to be grossly normal and was removed. Exploration of the abdomen revealed a diverticulum arising about ten inches proximal to the ileocecal valve. This diverticulum had its own mesentery and measured approximately 4.5 inches in length. At its tip it was attached to the under surface of the umbilicus. At this point of attachment the diverticulum was edematous and indurated, and was surrounded by a greatly thickened omentum. There was a rather marked increase in turbid peri-

toneal fluid. At the tip of the diverticulum there appeared to be a perforation around which the omentum had wrapped itself. The Meckel's diverticulum, acting as a band, had permitted the terminal ileum to herniate beneath it so that there was almost a complete small bowel obstruction. The ileum proximal to this band was rather markedly dilated, while the ileum lying in the pelvis was collapsed (Fig. 1). There were no pathologic changes in the bowel wall. To facilitate the operative procedure the rectus muscle was transected and the entire diverticulum, together with its attachment to the umbilicus, exposed. The diverticulum was freed from its attachment to the umbilicus. After transecting and ligating its mesentery, the diverticulum was excised over a Payr clamp. The resection of the diverticulum released the obstruction, permitting the distended bowel to resume its normal caliber. Sulfanilamide crystals were sprinkled freely into the wound, and the wound closed in layers without drainage.

Pathologic Diagnoses: The removed specimens consisted of: (1) Meckel's diverticulum, gastric type. (2) Foreign body in Meckel's diverticulum, with erosions of mucosa and formation of early gastric ulcer. (3) Acute appendicitis, early. (4) Hyperplasia of lymphoid tissue of appendix, advanced. The pathologist noted that this was an interesting specimen of Meckel's diverticulum which was lined with gastric mucosa of both a fundal and pyloric character. A foreign body, presumably a wood splinter, had become impacted causing erosion and partial digestion of the damaged mucosa, similar in type to that seen in gastric ulcers. (Patient stated that he had had the habit for many years of chewing match sticks; and one of these may have been the foreign body observed by the pathologist.)

An interesting incidental finding was noted by the pathologist. This was a very early acute appendicitis, with a small focus of material in the exudate and diffuse catarrhal appendicitis, characterized by marked hyperplasia of the lymphatic apparatus.

The patient made an uneventful postoperative course and was returned to duty.

COMMENT.—It is interesting to speculate as to which of this patient's pathologic conditions was responsible for his admission into the hospital. It is thought that the intestinal obstruction was probably the primary pathology. The history of recurrent, rhythmical pain, which the patient described as cramps, together with the findings at the time of operation of a small bowel obstruction, are evidence in support of this contention. Certainly, the acute diverticulitis was an important contributory factor. The fever, the leukocytosis, with the shift to the left of the polymorphonuclear element, are indicative of acute inflammatory changes which, together with the intestinal obstruction, probably cover the entire picture. The intestinal obstruction was of the simple mechanical type and there was no evidence of strangulation to account for the leukocytosis and abdominal tenderness. The finding of early acute appendicitis probably aggravated the complaint, but was not in itself responsible for the patient's picture.

SUMMARY

An unusual case of Meckel's diverticulum has been presented. This case was most interesting in that it presented an acute Meckel's diverticulitis, associated with a peptic ulcer, intestinal obstruction, and, coincidentally, with an acute early appendicitis.

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[1] Womack, Nathan A., and Siegert, R. B.: Surgical Aspects of Lesions of Meckel's Diverticulum. ANNALS OF SURGERY, 108, 221, August, 1938.

BRIEF COMMUNICATION

ABSORBABLE SPONGE TESTS*

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THE NONIRRITATING FOREIGN BODY which can be left in the tissues for one purpose or another has become a problem of more and more interest in all fields of surgery. Until very recently only nonabsorbable material was ever introduced in any considerable physical bulk, for instance steel plates and screws in open reductions of fractures. Absorbable solid material was limited to catgut which is slightly irritating, but, because it is absorbed, does not promote the persistence of infection. Nonabsorbable materials—silk, cotton and silver—are also slightly irritating, but are, obviously, introduced in very small quantity, and, if infection does not occur, induce a minimal foreign body reaction, finally becoming encapsulated by varying amounts of fibrous tissue. Large amounts of cotton in the form of gauze sponges or compresses when accidentally left in a wound usually lead sooner or later to trouble.

There are, however, situations in surgery, problems of hemostasis chiefly, and of prevention of adhesions, where it is highly desirable to be able to leave absorbable nonirritating material in considerable bulk in an operative wound or an accidental wound. Even before battle casualties gave renewed impetus to the search for absorbable sponge such investigation was in progress in many laboratories. As a result, a number of materials have already been tested and are now in the stage of clinical investigation. The most promising to date have been fibrin foam prepared from human blood, gelatin, and gauze or cotton rendered absorbable by oxidation.

Of necessity, these products must be constantly checked to insure against any alteration which might render them irritating or nonabsorbable. Minimal contamination may result in established infection if an irritating foreign substance *in bulk* is left in the wound. Moreover, new materials are proposed which likewise need to be checked in animal tissues. After a study of various tissue reactions to absorbable gauze and to other absorbable sponges in larger laboratory animals it became apparent that there was a need for a simple standard test of these materials in smaller, less expensive animals. Possible contamination had to be reduced to a minimum so that an irritating product could be evaluated without a second factor which might evoke a tissue response. *It is not possible to judge a solid foreign body in an open wound* in a laboratory animal. Moreover, it is extremely difficult to prepare the skin of most

* This work was carried on under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Columbia University.

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laboratory animals so that clean wound healing may be expected if a foreign body is introduced. If infection develops it may be suspected that the irritating properties of the material being tested have contributed to this result, but cultures should be sterile before a product is condemned. Extraordinary precautions, therefore, must be taken, and in tests in somewhat over 100 white rats, an animal chosen after considerable trial and error, the following method has been found satisfactory, not too time-consuming and not too expensive. This is a method previously used by one of us (Lattes, University of Turin), for the study of transplantable animal tumors.

PROCEDURE

Nembutal anesthesia: 4 per cent solution intraperitoneal, 1 cc. for a 200-gram rat. It is better to have the anesthesia a little light and supplement with ether, open cone, if necessary. The animal is then tied on a rat board, and the whole back shaved with electric clippers and painted with 4.5 per cent iodine. Sterile instruments are used for each animal and discarded. The operator is masked, scrubbed and gloved, but does not change gloves unless he touches the skin of the animal by accident.

A transverse incision 2 cm. long is made with scissors in the interscapular region. The scissors are then discarded and a tunnel is made by holding up the distal skin edge with forceps, introducing a clamp in the midline and pushing it toward the sacral region where it is opened to spread the very lax subcutaneous tissue a little. Every care is taken not to touch the skin edge. With the skin edge still held up so that the mouth of the wound is wide open a glass tube (7-Mm. caliber) containing the sample to be tested is introduced, avoiding the skin edge, to the limit of the tunnel made by the clamp. A glass rod (4 Mm.) is then run through the tube and the pledget extruded into the tissues. With the clamp and the forceps the two corners of the wound are held up by the operator, and the wound is closed with two Michel clips placed by the assistant. The final site of implantation is, therefore, 5 or 6 cm. from the skin wound. Moreover, the animal cannot chew the wound in the interscapular region, as happened frequently when we formerly used the lower back for the incision.

Autopsy can then be performed on the day of choice. After chloroform the back is wet with 70 per cent alcohol so as to avoid contamination from flying hair. A U-shaped incision is made with the base of the U slightly cephalad to the skin incision, and the sides well out along the flanks. The whole flap of skin can then be pulled toward the tail, exposing the tunnel in the subcutaneous tissue and the site of implantation of the sponge. A culture can be taken from the tissues at this site if there is any inflammation. If the foreign body is still unabsorbed, in part or in whole, its relation to the tissues can be ascertained. It may lie wholly inert, or it may be encysted or encapsulated. These variations depend on the nature of the material under investigation. With irritating materials a cavity may be formed lined by fibrin and polymorphonuclear leukocytes, and containing

sterile purulent fluid. With this technic it is gratifying to see how little tissue damage is done along the tunnel leading from the wound to the site of implantation. There is a minimum of inflammation. Where there has been interference with healing of the skin wound (ordinarily from trauma in the cage postoperatively) the site of implant in usually still protected by distance, and cultures will be sterile.

The size of the trial pledget is a matter of choice. It should be large enough to constitute a mass of appreciable physical bulk. We have used a square centimeter of material. The gauze has been 8-ply. Cotton or other sponges are cut to approximately the same bulk. Relative times of absorption of different materials, limited of course, to the reaction of this one tissue, can thus be roughly estimated. Many factors, however, influence the rate of absorption, and any product released for clinical investigation should first be thoroughly studied in various tissues of larger animals.

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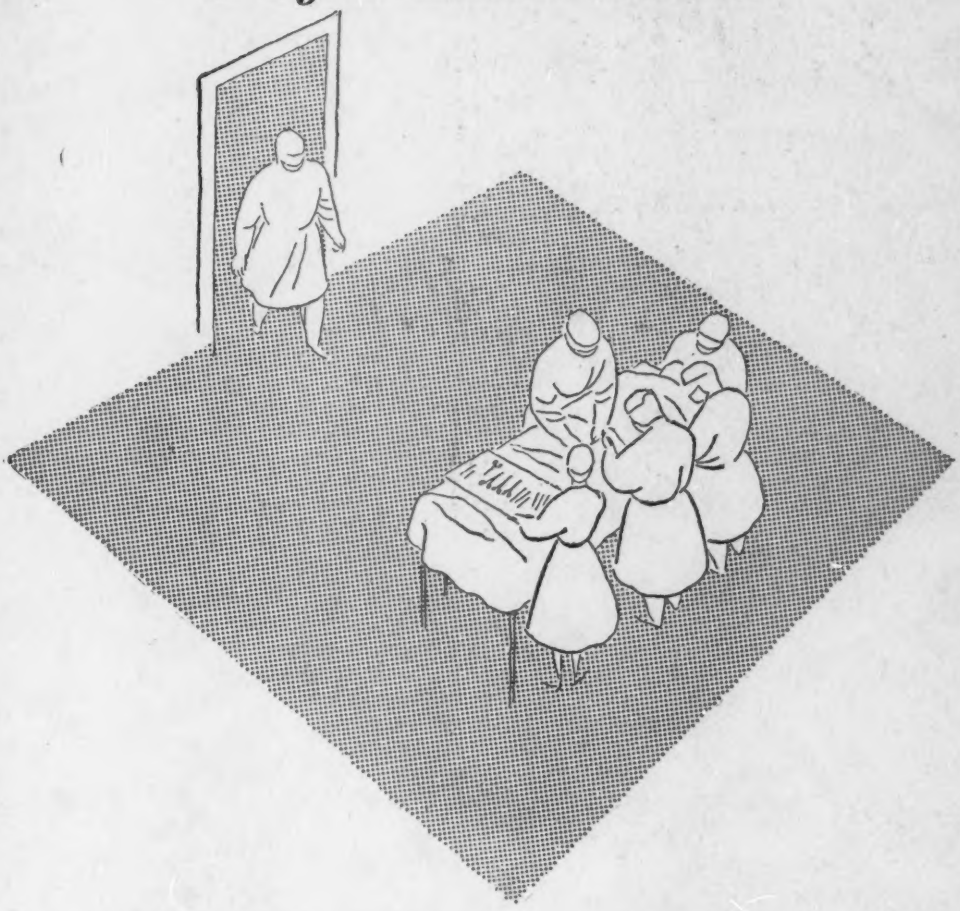

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